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(71) **Applicant: METANOLOGY CORPORATION** [US/US]; 4625 Alexander Drive, Suite 200, Alpharetta, GA 30022 (US).

(72) **Inventors: ZYGMONT, David, A.**; 360 Dashing Wave Lane, Alpharetta, GA 30005 (US). **WANG, Wei**; 1410 Portmarnock Drive, Alpharetta, GA 30005 (US).

(74) **Agents: FLOAM, D., Andrew** et al.; Needle & Rosenberg, P.C., Suite 1200, 127 Peachtree Street, N.E., Atlanta, GA 30303-1811 (US).

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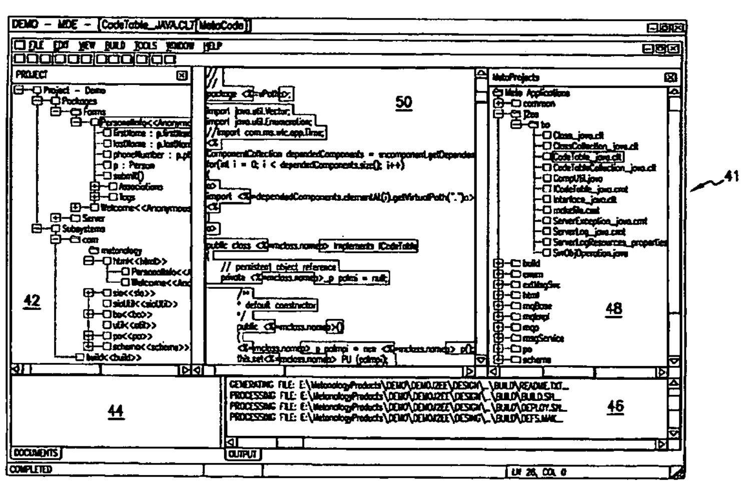
(54) **Title:** SYSTEM AND METHOD FOR METAPROGRAMMING SOFTWARE DEVELOPMENT ENVIRONMENT



(57) **Abstract:** A meta-development environment (MDE) allows users to develop and maintain application software systems independently of architectures and to develop and maintain architecture-dependent aspects of application software systems independently of applications. The user provides the MDE with an object model expressed in an object modeling computer language and a set of one or more metaprograms expressed in a computer programming language. The object model represents an application (Figure 1, #12), and the metaprograms (Figure 1, #14) reflect a computer system architecture. The meta-machine (Figure 1, #10) binds the object model components to the metaprograms to generate a software system (Figure 1, #16) operable on that architecture.

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SYSTEM AND METHOD FOR METAPROGRAMMING SOFTWARE DEVELOPMENT ENVIRONMENT

CROSS-REFERENCE TO RELATED APPLICATION

The benefit of the filing date of U.S. Provisional Patent Application Serial No. 60/192,431, filed March 28, 2000, entitled "SYSTEM AND METHOD FOR METAPROGRAMMING SOFTWARE DEVELOPMENT ENVIRONMENT," is hereby claimed, and the specification thereof is incorporated herein in its entirety by this reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to software system modeling, software development tools and computer-assisted software engineering and, more specifically, to generating software code from visual models of a software system.

2. Description of the Related Art

With software systems becoming increasingly complex, so is the task of creating or engineering them. Application programs for typical complex business enterprise applications, such as operating a bank, healthcare system, accounting department, payroll department or call center, can consist of hundreds of thousands of lines of code. Graphical user interfaces, networked computing, distributed object-oriented computing, transaction processing, database technology and other advances in computing have all contributed to the skyrocketing increase in program complexity. While in earlier days of computing a single programmer could effectively comprehend an entire task, envision a suitable program structure, and write all the (perhaps a few hundred or few thousand lines of) code to implement it on a computer, these tasks become unmanageable for unaided programmers as program size and complexity increase. Complex programs (which are perhaps better termed "software systems" because they can include myriad individual pieces of software) are more often written by teams of programmers working in concert and employing general

engineering principles to guide the product development effort. Software development tools are used to organize a development project and integrate third-party software into the overall system to the extent such software may be commercially available and useful to the project.

An engineering principle that has long been difficult to apply efficiently to software is the construction of complex systems from pre-manufactured sub-systems and parts. The difficulty arises in part because the majority of business enterprise software systems are custom items, written by software developers to each customer's specifications. The difficulty also stems in part from the rapid advances in computer technology that require software systems to be rewritten every few years to keep up with the technology of the computing platforms on which they are run. Although the business applications themselves often remain relatively stable for years, entirely new software generally must be written to implement those applications on new platforms.

One of the goals of object-oriented (OO) programming is code re-use. It was envisioned that object classes initially created in one application development effort could later be used if a similar class were needed in another development effort. Frameworks, which are essentially collections of classes, have been developed to similarly ease the tasks of application program developers. Specialized frameworks are commercially available to software developers to aid development of specific types of software systems, such as business enterprise application software systems. Many of the advances in OO computing relate to distributed computing systems, in which objects used in a software system can be located on different computers that are connected to one another via a network. Platforms such as JAVA 2 ENTERPRISE EDITION (J2EE) from Sun Microsystems, and MICROSOFT DNA and MICROSOFT .NET from Microsoft Corporation are directed to problems that software developers face in developing OO software systems for client-server environments such as the World Wide Web. (Because terminology referring to a specified "platform" is commonly used somewhat ambiguously in the art to mean both software commercially available under the specified name and a computer

operating under that software, it is preferred in this patent specification to use terminology referring to a specified "architecture" to mean the complete hardware and software computer or system of computers operating under software of the specified name and any other system software, such as application server software and database software; to the extent the term "platform" may be used, it is intended to mean a subset of the architecture.) Whenever the architecture of a business enterprise's system changes significantly, the enterprise calls upon software engineers or developers to rewrite application programs to conform to the new architecture. As each newly developed platform becomes commercially available, software developers will face the task of again rewriting software systems for them to implement the same applications that had been used on the platforms that preceded them. Typically, the amount of existing or legacy code that can be re-used in developing the new software is small in comparison to the amount that must be written anew. The major cause of this inefficiency is that, despite programmers' increasing efforts to divide software (e.g., through object-oriented technology) into manageable levels of abstraction, where the higher levels represent the problem from more of a business or user perspective, leaving the lower levels to implement the more machine-dependent and routine computing functions, many of the architecture-dependent portions of the software system typically remain inextricably bound up with the architecture-independent portions.

The rapid pace of architecture development not only causes business enterprises to expend great sums of money to periodically conform their existing applications, but it also hinders the development of new applications. The initial step of merely investigating which of the myriad architectures to base a proposed application upon can account for a significant portion of the development project budget. Furthermore, architecture advances that become commercially available after the development effort is well underway can delay the project and increase its cost if it is decided that the application should support the newly available architecture.

Object-oriented software engineering has been greatly aided by the

development of modeling languages. The Unified Modeling Language (UML), promulgated by the Object Management Group (OMG), has become the standard notation for describing an OO software system. (See OMG Unified Modeling Language Specification, version 1.3, Object Management Group, Inc., Needham, Massachusetts.) The UML is not tied to any specific programming language or architecture but rather defines a graphical notation for expressing concepts common to most OO languages, such as classes, associations, aggregations, inheritance and containment. The versatility of the UML allows it to be used not only as an aid to software developers in describing and modeling software systems but for other purposes as well, including as an aid to non-programmers in describing business processes and other processes. The UML is well-known to persons of ordinary skill in the art to which the invention described below pertains and is therefore not described in further detail in this patent specification.

Software development tools that build upon the UML are commercially available. RATIONAL ROSE® from Rational Software Corporation, which was involved in developing the UML standard, provides the software developer with a set of visual modeling tools for software development in client/server, distributed enterprise and real-time systems environments. Among other features, RATIONAL ROSE allows a software developer to describe and visualize a software system in the UML, model its operation, and generate portions of the software code.

Code generators are tools that software developers can use to reduce the amount of manual coding required. A code generator uses as an input a description of the application that the developer has written in some high-level language or notation and, in response, generates as an output software (source) code that implements the application. Code generators are essentially tied to specific architectures. In other words, a code generator for one architecture will generally not generate code usable on another architecture; rather, another code generator must be used to generate code usable on that architecture. Code generators are believed by some to be advantageous and helpful tools because they attempt to exploit idiosyncracies of the architecture to

maximize coding efficiency. As a result, code generators typically generate code in which the architecture-independent aspects are even more closely and inextricably bound up with the architecture-dependent aspects than manually written code.

It would be desirable to provide a software development environment in which the architecture-dependent aspects of an application software system are separable from the application itself. The present invention addresses these problems and deficiencies and others in the manner described below.

SUMMARY OF THE INVENTION

The present invention relates to a software development environment referred to in this patent specification as a meta-development environment (MDE) that allows a user to develop and maintain application software systems independently of architectures and to develop and maintain architecture-dependent aspects of application software systems independently of applications.

The MDE includes a meta-machine and a suitable user interface. The user provides the MDE with an object model expressed in an object modeling computer language, such as the Unified Modeling Language (UML), that represents an application. The user also provides the MDE with a set of one or more metaprograms reflecting a computer system architecture. Under user control, the meta-machine binds the object model components to the metaprograms to generate a software system.

The software system generated in the above-described manner is operable on a computer system having an architecture of the type reflected by the set of metaprograms and not on systems having other architectures. Nevertheless, the same object model can be used with multiple architectures. To create a software system that implements the same application on a system having another architecture, the user causes the meta-machine to bind the object model representing the application to another set of metaprograms that reflect the other architecture. The user can provide the metaprograms by writing them or obtaining them from a vendor or other source.

In this manner, an application software system can be quickly and easily developed for a newly developed architecture by creating a suitable set of metaprograms reflecting the new architecture.

Conversely, the same set of metaprograms can be used with multiple object models. To create a software system that implements another application on a computer system having the same architecture as an existing system for which corresponding metaprograms exist, the user causes the meta-machine to bind the object model representing the other application to the set of metaprograms reflecting the architecture. In this manner, software developers and even persons with minimal knowledge of architectures or coding can develop new application software systems by expressing the application in the UML or other suitable object modeling language.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate one or more embodiments of the invention and, together with the written description, serve to explain the principles of the invention. Wherever possible, the same reference numbers are used throughout the drawings to refer to the same or like elements of an embodiment, and wherein:

Figure 1 is a process flow diagram illustrating the operation of a meta-development environment (MDE);

Figure 2 is a schematic block diagram of a computer system programmed to operate in accordance with a MDE;

Figure 3 is a screen display illustrating the MDE user interface;

Figure 4 is a schematic block diagram of a MDE;

Figure 5 is an overview of the drawing sheets with a UML diagram illustrating a meta model;

Figure 5A is a portion of the UML diagram of Fig. 5;

Figure 5B is another portion of the UML diagram of Fig. 5;

Figure 5C is another portion of the UML diagram of Fig. 5;

Figure 5D is another portion of the UML diagram of Fig. 5;

Figure 5E is another portion of the UML diagram of Fig. 5;

Figure 5F is another portion of the UML diagram of Fig. 5;

Figure 6A is a portion of a flow chart illustrating loading the object model into the meta model;

Figure 6B is a continution of the flow chart of Fig. 8A;

Figure 6C is a continuation of the flow chart of Figs. 8A-B;

Figure 7 is a UML sequence diagram illustrating preparing to execute component metaprograms;

Figure 8 is a UML sequence diagram illustrating executing component metaprograms

Figure 9 is a UML sequence diagram illustrating executing class metaprograms;

Figure 10 is a UML sequence diagram illustrating compiling a metaprogram;

Figure 11A consists of tables describing system enumerations in the meta model;

Figure 11B is a continuation of the tables of Fig. 11A;

Figure 12A consists of tables describing the class Attribute of the exemplary meta model;

Figure 12B is a continuation of Fig. 12A;

Figure 12C is a continuation of Fig. 12A-B;

Figure 13A is a table describing the class AssociationRole of the exemplary meta model;

Figure 13B is a continuation of Fig. 13A;

Figure 14A consists of tables describing the class Component of the exemplary meta model;

Figure 14B is a continuation of Fig. 14A;

Figure 15A consists of tables describing the class Generalization of the exemplary meta model;

Figure 15B is a continuation of Fig. 15A;

Figure 16A is a table describing the class MetaClass of the exemplary meta model;

Figure 16B is a continuation of Fig. 16A;

Figure 16C is a continuation of Fig. 16A-B;

Figure 16D is a continuation of Fig. 16A-C;

Figure 16E is a continuation of Fig. 16A-D;

Figure 17A is a table describing the class MetaObject of the exemplary meta model;

Figure 17B is a continuation of Fig. 17A;

Figure 18A is a table describing the class Model of the exemplary meta model;

Figure 18B is a continuation of Fig. 18A;

Figure 19A is a table describing the class Operation of the exemplary meta model;

Figure 19B is a continuation of Fig. 19A;

Figure 19C is a continuation of Fig. 19A-B;

Figure 20 is a table describing the class Package of the exemplary meta model;

Figure 21A is a table describing the class Parameter of the exemplary meta model;

Figure 21B is a continuation of Fig. 21A;

Figure 22 is a table describing the class Realization of the exemplary meta model;

Figure 23 is a table describing the class Subsystem of the exemplary meta model; and

Figure 24 is a table describing the class Tag of the exemplary meta model.

DETAILED DESCRIPTION

As illustrated in Fig. 1, a meta-machine 10 receives as inputs an object model 12 and a set of one or more metaprograms 14 and, in response to these inputs, produces as an output a software system 16. Software system 16 can be any portion or all of a software system operable on a computer system (not shown). An important concept underlying the invention is that architecture is separated from application. Object model 12 expresses or reflects the business logic or application logic, and metaprograms 14 express or reflect the architecture of the computer system on which software system 16 is to be operated.

The term "application" as used in this patent specification refers to the work or task to be accomplished by software system 16. The "logic" of an application is how the task is to be accomplished. Note that logic can be expressed in computer programming languages, modeling languages, mathematical notations, and other means. Software system 16 is an expression of object model 12 in a selected computer programming language, such as JAVA or any other suitable programming language. Although the present invention can be used for generating software systems 16 that address the tasks facing business enterprises such as banks, manufacturers, retailers, healthcare systems and financial and other service providers, the present invention can be used for generating software systems 16 that address tasks facing consumers and other individuals. Thus, the term "business" (e.g., "business logic"), to the extent it is used in this patent specification, is used only for purposes of convenience and illustration.

As noted above, the term "architecture" as used in this patent specification refers to that which uniquely characterizes how the complete hardware and software computer system operates. Thus, for example, two computer systems having different operating systems or environments (e.g., MICROSOFT WINDOWS, MICROSOFT DNA, MICROSOFT .NET, JAVA 2 ENTERPRISE EDITION (J2EE), ENTERPRISE JAVA BEANS (EJB), CORBA, etc.) but otherwise having identical operating hardware and software are considered for purposes of this patent specification to have

different architectures from one another. Likewise, two computer systems having the same operating system or environment but having differences in database systems or back-end servers or other operating hardware or software are considered for purposes of this patent specification to have different architectures from one another. By separating architecture from application, the present invention allows software developers or other users to create, maintain and revise an object model 12 independently of architectures of the computer systems on which a resulting software system 16 may operate and, conversely, allows such users to create, maintain and revise metaprograms 14 independently of any application that a resulting software system 16 may implement or embody.

Object model 12 is expressed in a suitable object modeling computer language, such as the Unified Modeling Language (UML). As persons skilled in the art to which the invention pertains understand, UML is a visual modeling language or notation in which a software developer or other individual can express an object-oriented (OO) system. (See, e.g., Figs. 5A-F) The UML as well as OO programming concepts are well-known in the art and therefore not described in this patent specification.

Note that object model 12 only reflects or represents software system 16; it is embodied in a modeling language and not a programming (source code) language and is therefore not operable on a computer system. In the lexicon of the UML, such an object model comprises components that realize object classes. As described in further detail below, meta-machine 10 generates a software system 16 usable on a computer system having the architecture reflected by metaprograms 14 by binding the components to metaprograms 14. Software system 16 can include source code in any suitable programming language as well as mark-up language code (e.g., HTML), database schema code, and any other software code usable on the computer system. The term "code" as used by itself in this patent specification is intended to refer to all such code. As described below, a metaprogram comprises a combination of code and metacode.

As illustrated in Fig. 2, meta-machine 10 operates under the control of a user (not shown) who is provided with a computer system on which a meta-development environment (MDE) 18 is operating, i.e., a computer system programmed with suitable MDE software. The computer or computer system operated by the user can be a conventional personal computer. As described below, MDE 18 includes a user interface 20 that operates in accordance with conventional windowing graphical user interface (GUI) paradigms. Accordingly, to interface with the user, the computer includes a mouse 21, a keyboard 22 and a video display 24. The computer also includes other hardware and software elements of the types generally included in conventional personal computers, such as a processor 26, disk storage device 28 such as a hard disk drive, input/output interfaces 30, a network interface 32, and a removable read/write storage device 34 such as a drive that uses a CD-ROM or a floppy disk 36. The software elements of the programmed computer, such as MDE 18, are shown for purposes of clarity and illustration as executable in a main memory 38, but as persons skilled in the art understand they may not in actuality reside simultaneously or in their entireties in memory 38. The computer has other hardware and software elements of the types conventionally included in personal computers, such as an operating system, but are not shown for purposes of clarity. Note that software elements such as MDE 18, object model 12 and metaprograms 14 can be loaded into the computer from another source via disk 36 or a network 40 or similar media. Similarly, such software elements can be transferred from the computer to another destination via disk 36 or network 40 or similar media. Note that embodiments of the present invention include not only methods and systems but also computer program products in which MDE 18, object model 12, metaprograms 14 or other software elements are carried on disk 36, network 40 or similar media.

Object models 12 and metaprograms 14 can be provided in any suitable manner. As described below, it is contemplated that some may be written by the user of MDE 18 or an associate of the user. Alternatively, the user or company with which the user is associated can purchase object models 12 or metaprograms 14 from a

developer or other vendor of such items.

In one scenario contemplated within the realm of the invention, the individual or company using MDE 18 creates an object model 12 that reflects a business application and purchases metaprograms 14 that reflect the architecture of the company's computer system from a vendor. If the company subsequently changes or updates its computer system such that the architecture changes, the company can purchase new metaprograms 14 that reflect the new or changed architecture. Thus, object model 12 ideally need only be written once; the company can generate new software systems 16 as needed to keep pace with subsequent changes in its computer system architecture by purchasing the corresponding metaprograms from a vendor or having them written in-house (i.e., by company personnel). The invention thus addresses the fact that new architectures are being developed at a faster pace than new applications. Indeed, typical business applications such as banking, finance and accounting, tend to remain on average relatively unchanged for years while it seems that a highly-touted new architecture is introduced each year. In a scenario known to have been common in the prior art, technologists within a business enterprise would often urge a changeover to the newest architecture for performance or other technical reasons, while business personnel may have been reluctant to sanction the associated software development effort for economic reasons. Using the present invention, a changeover to a new architecture can be made relatively economically and efficiently.

In another scenario contemplated within the realm of the invention, the user or company using MDE 18 creates in-house or purchases from a vendor metaprograms 14 that reflect the architecture of the company's computer system. Once such metaprograms 14 are provided, the company can obtain any number of object models 12, either by creating them in-house or by purchasing from vendors, that reflect various business applications. When a new application is desired, the company can generate a new software system 16 by creating a corresponding object model 12 or purchasing one from a vendor. Other scenarios that involve combinations of the two described above are also contemplated.

Note that because object models 12 are not written in a programming language but rather a modeling language, even non-programmers and other non-technologically savvy individuals can create them. Thus, a company can employ business analysts or other non-technologists who are the most familiar with the application to create an object model 12. Programmers or other technologists who understand computer programming and architectures can write metaprograms 14. The business analyst or other non-technologist who creates object model 12 need not have any knowledge of metaprograms 14 or the architectures they reflect. The technologists who create metaprograms 14 need not have any knowledge of object model 12 or the business application it reflects.

A metaprogram is a mix of metacode expressed in a traditional programming language and output (code). In a metaprogram, metacode is distinguishable from the code by indicating the beginning of the metacode with an opening delimiter (e.g., the characters “<%”) and indicating the end of the metacode by a closing delimiter (e.g., the characters “%>”). For example, an example of metaprogram 14 written in JAVA and outputting hypertext mark-up language (HTML) is shown below:

```
<%
if (attribute.hasStereotype("text") {
%>
  <input type="text" name="<%=attribute.name%>"…
<%
//more metacode here
%>
```

In accordance with the above example, when MDE 18 executes this metaprogram 14 against object model 12, the metacode causes the code to be output (to an output file) if the attribute of object model 12 has a stereotype “text” and does not cause the code to be output if the object attribute does not have that stereotype. Also note the <%=attribute.name%> construct. This is called a meta substitution and is replaced with the value of the model element to which it refers; in this case, the name of the attribute. This process is described in further detail below.

To use MDE 18, the user loads MDE 18 (e.g., via disk 36) into the computer and launches or initiates its execution in the conventional manner of an application program. As illustrated in Fig. 3, user interface 10 provides a main window via which the user can interact with MDE 18. The primary graphical elements of this window include a project explorer panel 42, a documentation panel 44, a status panel 46, a metaproject explorer panel 48 and a metaprogram editor panel 50.

Project explorer panel 42 lists one or more object models 12. Software tools for creating and editing object models are well-known and commercially available. A user can create object model 12 using such a tool and then load it into MDE 18 via disk 36, network 40 or other suitable media. Using the conventional file folder GUI concept, a graphical indication of each object model 12 loaded into MDE 18 is displayed in the form of a file folder and its name. Grouped under each file folder are the names of elements that persons familiar with object modeling will understand are commonly included in an object model: Packages, Subsystems, Associations, Association Roles, Attributes, Components, Generalizations, Meta-classes, Meta-objects, Models, Operations, Parameters, Realizations and Tags. Using mouse 21 (Fig. 2) or other means for selecting graphical elements, the user can select any element of any of the loaded object models.

Documentation panel 44 displays any documentation that may be associated with elements of object model 12. As well-known in the art, the UML convention provides a means for associating documentation with elements of an object model. Persons creating an object model 12 will therefore readily appreciate how documentation is associated with model elements without further elaboration herein. The documentation for a selected object model element is displayed in documentation panel 44.

Status panel 46 displays the activity of meta-machine 10 and metaprograms 14. Meta-machine 10 indicates to the user the progress of its operation by outputting status messages to status panel 46. MDE 18 directs to status panel 36 certain output

of metaprograms 14 indicating their progress, indicating errors, and warning of potential problems in object model 12 that prevent their successful execution.

Metaproject explorer panel 48 displays the structure of loaded metaprojects. A metaproject is a collection of metaprograms 14 that together define an architecture. Thus, it is the metaprograms 14 of a selected metaproject that meta-machine 10 binds to the selected object model 12. A user can load metaprograms 14 from an external source via disk 36, network 40 or other medium or can create them within MDE 18 as described below. Using the conventional file folder GUI concept, a graphical indication of each metaproject in MDE 18 is displayed in the form of a file folder and name. Names of metaprograms 14 are grouped under each file folder. Using mouse 21 or other means for selecting graphical elements, the user can select the metaproject into which a new metaprogram 14 is to be loaded and can select metaprograms 14 for deletion, editing, renaming, saving and so forth. Sub-folders can be created to organize a hierarchy of metaprograms 14.

The term "meta-application" can be used to refer to a set of metaprojects and can also be indicated by a file folder icon and name. A metasolution file is associated with each meta-application. The metasolution file contains the name of the associated meta-application, the names of the metaprojects in the meta-application, and the names and properties of the metaprograms in each of those metaprojects.

As noted above, there can be any suitable number and type of metaprograms 14. Examples of metaprogram output (code) can include: an implementation of software system 16 in a programming language; database schema and file formats appropriate to store persistent data of software systems; software (scripts) used to build software system 16; software used to install, maintain and remove software system 16; internal system documentation used to maintain software system 16; Application Programming Interface (API) documentation describing the programming interfaces used to program software system 16; and user documentation describing the behavior of software system 16 to users.

Although there can be any suitable number and type of metaprograms 14, in the illustrated embodiment of the invention MDE 18 recognizes four categories of metaprograms 14: component, class, model and utility. Each of metaprograms 14 is assigned one of these categories to assist MDE 18 in determining how to execute it. Nevertheless, in other embodiments of the invention metaprograms 14 can be categorized differently or not divided into categories at all.

Meta-machine 10 runs each component metaprogram in a metaproject once. Component metaprograms can generate material used by all the classes in the component that are created by the class metaprograms in the same metaproject. Utility software, software installation, build software and documentation are typical outputs of component metaprograms.

Meta-machine 10 runs each class metaprogram in the selected metaproject once for each class realized in the component bound to the metaproject. Class metaprograms can generate the implementation of a class in object model 12. They add additional attributes and operations on each class in object model 12 to accommodate the requirements of the computer architecture or platform on which software system 16 is to execute.

Model metaprograms are similar to component and class metaprograms, but rather than generating the implementation of a software system from an object model of that software system, they interpret the object model of the software system and add model elements to it. For example, a model metaprogram may create additional classes along with attributes, operations, associations, create new components, realize classes in the components and map them to metaprojects as the model metaprogram sees fit. Through a meta model, described in detail below, model metaprograms can analyze object model 12 and expand the model. The new model elements are added so that component and class metaprograms can operate on them. This permits the identification of patterns in object models so that the mechanical work of modeling the detail of the pattern is foregone.

Utility metaprograms can provide general support services to metaprograms of the other types.

The metaprojects and their metaprograms 14 are not only displayed in a manner resembling a conventional hierarchical file system of folders but are actually stored on such a file system of the computer (e.g., on disk 28). When the user issues a command to create a new metaproject, MDE 18, starting from the directory that contains the then-loaded metasolution file creates a folder of the same name as that of the metaproject. That folder stores the metaprograms 14 in the new metaproject.

Components are bound to metaprojects by the value of their implementation target. As persons of skill in the art recognize, an implementation target can be set by using the user-defined extensions of an object modeling language. Using the UML, the implementation target can be set by either the value of the implementation target tag or the component's stereotype.

When a user selects one of metaprograms 14 or chooses to create a new one, user interface 20 displays it in metaprogram editor panel 50. In panel 50 a user can view and edit the selected metaprogram 14. As an aid to the user's understanding of the displayed metaprogram 14, the user can activate a toggle command, in response to which user interface 20 causes either the metacode or the code to be highlighted, i.e., displayed in a distinguishing tone or color. In other words, if metacode is highlighted, toggling causes the code to become highlighted and the metacode to become un-highlighted. If the code is highlighted, toggling causes the metacode to become highlighted and the code to become un-highlighted. In this manner, a user can quickly and easily distinguish the code from the metacode. In Fig. 3, note that the metacode is shown highlighted.

Note that although a graphical user interface 20 is included in the illustrated embodiment of the invention, in other embodiments user interface 20 can operate in accordance with any other suitable paradigm, such as the command line-based interface of the type included in, for example, UNIX and DOS systems.

As illustrated in Fig. 4, in addition to meta-machine 10 and user interface 20, MDE 18 includes a metaproject loader 52 and a model loader 54 for loading metaprojects (i.e., groups of one or more metaprograms 14) and object models 12, respectively, as indicated above with regard to user interface 20. Elements of user interface 20 include: a command interpreter 56 that interprets user interactions with graphical input elements such as pull-down menus, buttons and folders and other icons; a status monitor 58 that gathers and displays the above-described information in status panel 46 (Fig 3); a metaprogram editor 60 that performs conventional text editing functions and other functions on metaprograms 14 via panel 50 (Fig. 3) as described above; a metaproject explorer 62 that performs the above-described functions via panel 48; a project explorer 64 that performs the above-described functions via panel 42; and a documentation monitor 66 that displays documentation in panel 44 as described above.

Any metaprograms 14 that are created or edited using metaprogram editor 60 or loaded from an external source in uncompiled, i.e., source code, format, they can be compiled into object code format. Metaprograms 14 are compiled into executable units of a suitable programming language such as Java. In Java, they are compiled into Java class filed. Prior to compilation they are converted into syntactically correct Java source code. As illustrated in Fig. 10 in UML sequence diagram format, the steps of converting one of metaprograms 14 into a compiled Java class include: creating a file to hold the Java source code, using the root name of metaprogram 14 concatenated with ".java" as the file name, and writing the class header. The class header for component metaprograms is "class 'root filename'". The converting steps further include, for each block to be output into the Java source code file: determining the block's type (i.e., CODE, METACODE or META SUBSTITUTION); and, for a TEXT block, appending a call to generator.write with the quoted text block as a parameter to the Java source code file, for a METACODE block, appending the block to the Java source code file, and for a META SUBSTITUTION block, appending a call to generator.write with the block as a parameter to the Java source code file.

Once all blocks have been written to the Java source code file, an external Java compiler (i.e., not considered part of MDE 18 and therefore not shown) is invoked to compile the Java source code file.

A meta model 68 is also included in MDE 18. A UML model of meta model 68 is illustrated in Figs. 5A-F. Meta model 68 is an object model of an object model. For example, when object model 12 is loaded into MDE 18 and selected by the user, MDE 18 loads object model 12 into meta model 68. To facilitate modeling an object model, meta model 68 includes classes that represent the elements that object modelers typically include in object models. Although they may be referred to in the art by names other than the following, these object model elements include: associations, association roles, attributes, components, generalizations, classes, models, operations, packages, parameters, realizations, subsystems and tags. The corresponding class name in meta model 68 and a brief description of each class is as follows:

Association	An Association instance represents an association in the object model of a software system.
AssociationRole	An AssociationRole instance represents an association end in the object model of a software system.
Attribute	An Attribute instance represents an attribute of a class in the object model of a software system.
Component	A Component instance represents a component in the object model of a software system.
Generalization	An Generalization instance represents a generalization in the object model of a software system. A generalization exists whenever one class inherits from another class.
MetaClass	A MetaClass instance represents a class in an object model of a software system.
MetaObject	The base class of most objects in the meta model.
Model	The root element of an object model of a software system.
Operation	An Operation instance represents a method of a class in the object model of a software system.
Package	A Package instance represents a package in an object model of a software system.
Parameter	A meta parameter represents a parameter to a method in the model of a software system.
Realization	A Realization instance represents a realization of an interface by a class in the object model of the software system.

Subsystem	An instance of Subsystem represents a subsystem in the model of the software system. A subsystem is used to group components and typically affects the physical layout of implementation of the software system.
Tag	A Tag instance represents a tagged value bound to a model element in an object model of a software system.

Complete descriptions of the above-referenced classes are provided in Figs. 11A-24.

Figures 6A-C illustrate the process by which MDE 18 loads object model 12 into meta model 68. At step 70 MDE 18 opens the file embodying object model 12. As described above, object model 12 contains packages, subsystems, components and other elements. MDE 18 reads and processes these elements.

At step 72 MDE 18 finds a package in object model 12 that it has not yet processed in the loop between steps 72 and 76. At step 74 MDE 18 reads (package) meta-object attributes and processes the package. The processing includes: instantiating an object of the Package class ("meta package"); setting the stereotypes of the meta package to those of the package; setting the tag and value pairs of the meta package to those of the package; and adding the meta package to the collection of packages of meta model 68.

At step 78 MDE 18 finds a metaclass that it has not yet processed in the loop between steps 78 and 80. At step 82 MDE 18 reads and processes the class. This processing includes: instantiating an object of the Metaclass class ("meta class"); setting et the scope and name of the meta class to those of the class in object model 12; setting the meta class stereotypes to those of the class; setting the metaclass tags and values to those of the class; adding the new meta class object to the collection of metaclasses of meta model 68.

At step 84 MDE 18 loads all attributes of the class being processed into meta model 68. This loading includes, for each Attribute of the class: instantiating an object of the Attribute class ("meta attribute"); setting the scope, type, name and initial value of the meta attribute to those of the attribute in object model 12; setting the meta attribute stereotypes to those of the attribute; setting the meta attribute tags

and values to those of the attribute; and adding the new attribute object to the collection of attributes of the metaclass.

At step 86 MDE loads all operations. This loading includes, for each method of the class: instantiating an object of the Operation class ("meta operation"); setting the scope, return type and name of the meta operation to those of the method in object model 12; setting the operation stereotypes to the method stereotypes; setting the operations tags and values to the methods tags and values. This loading step further includes, for each parameter of the method: instantiating an object of the Parameter class ("meta parameter") and setting the type and name of the meta parameter to those of the parameter in object model 12; adding the meta parameter to the collection of parameters for the meta operation; and adding the new operation object to the collection of operations of the metaclass.

When all packages and all classes in those packages have been processed, at step 88 MDE 18 finds an association it has not yet processed in the loop between steps 88 and 90. At step 92 MDE 18 reads (association) meta-object attributes and processes the association. For each association in object model 12, this processing includes: instantiating an object of the Association class ("meta association"); setting the name of the meta association to that of the association in object model 12; setting the stereotypes of the meta association to those of the association; setting the tags and values of the meta association to those of the association; adding the new meta association object to the collection of associations of meta model 68; and instantiating an AssociationRole object ("meta role") for each association end. The processing further includes, for each meta role: setting the stereotypes of the meta role to those of the association end; setting the tags and values of the meta role to those of the association end; setting the meta class of the meta role to the MetaClass instances in the collection of metaclasses in object model 12 representing the class participating in the association end; setting the related role of each meta role to the other meta role; and adding the meta association to the collection of associations of meta model 68.

At step 94 MDE 18 loads association roles into object model 68. This loading step includes: instantiating an object of the AssociationRole class ("meta association role"); setting the name of the meta association role to that of the association role in object model 12; setting the stereotypes of the meta association role to those of the association; setting the tags and values of the meta association role to those of the association; adding the new meta association role object to the collection of associations of meta model 68; and instantiating an AssociationRole object ("meta role") for each association role. The processing further includes, for each meta role: setting the stereotypes of the meta role to those of the association end; setting the tags and values of the meta role to those of the association end; setting the meta class of the meta role to the MetaClass instances in the collection of metaclasses in object model 12 representing the class participating in the association end; setting the related role of each meta role to the other meta role; and adding the meta association to the collection of associations of meta model 68.

When all associations have been processed, at step 96 MDE 18 finds a subsystem it has not yet processed in the loop between steps 96 and 97. At step 98 MDE 18 reads and processes the subsystem. For each subsystem in object model 12, the processing includes: instantiating a Subsystem object ("meta subsystem"); setting the name of the meta subsystem to that of the subsystem in object model 12; setting the stereotypes of the meta subsystem to those of the subsystem; setting the tags and values of the meta subsystem to those of the subsystem; adding the new meta subsystem object to the collection of subsystems of meta model 68.

When all subsystems have been processed, at step 100 MDE 18 finds a component it has not yet processed in the loop between steps 100 and 102. At step 104 MDE 18 loads the component into object model 68. For each component in the software system's model, this loading step includes: instantiating a Component object ("meta component"); setting the name of the meta component to that of the component in object model 12; setting the stereotypes of the meta component to those of the component; and setting the tags and values of the meta component to those of

the component. The processing further includes, for each class realized in the component, getting the meta class corresponding to the class in object model 12 for the collection of meta classes of meta model 68 and adding it to the collection of meta classes of the component.

At step 105 MDE 18 establishes component dependencies. For each meta component in the collection of meta components of meta model 68, this processing includes: getting the components in the object model 12 on which the meta component depends and, for each such component gotten, get the corresponding meta component and add this meta component to the dependencies collection of the meta component being processed.

When all components have been processed, at step 106 MDE 18 then completes the loading process by saving the loaded meta model 68 (e.g., to disk 28). MDE 18 also displays a graphical representation (not shown) of the loaded meta model 68 in project panel 50.

When object model 12 has been selected and loaded into meta model 68 and a set of one or more metaprograms 14 has been selected, loaded and compiled as described above, the user can initiate the operation that causes MDE 18 to generate software system 16. Figures 7-9 are UML sequence diagrams illustrating this operation.

Within the project explorer of the user interface, the user right clicks "Subsystems" and selects "Build." At this point, meta-machine 10 performs the following steps shown in Fig. 7. First, MDE 18 retrieves all subsystems in the current model. Then, for each subsystem in the model, MDE 18 performs the following steps: retrieve the components in the subsystem; and generate each component, as further explained below with reference to Fig. 8.

As illustrated in Fig. 8, for each component to generate, MDE 18 retrieves the implementation target from the component. The implementation target is a stereotype of the component and binds the component to a metaproject. MDE 18 then: retrieves the current set of metaprograms ("metasolution"); retrieves the metaproject whose

name matches the implementation target of the component; initializes meta-machine 10; and retrieves the component metaprograms in the metaproject. For each component metaprogram, MDE 18 instructs meta-machine 10 to run the component metaprogram. MDE 18 then retrieves the meta-classes in the component and invokes the appropriate class metaprograms, as further explained below with reference to Fig. 9.

As illustrated in Fig. 9, MDE 18 retrieves the implementation target from the component for which it has been invoked. The implementation target is a stereotype applied to the component and binds the component to a metaproject. MDE 18 then retrieves the current set of metaprojects for the loaded metasolution. MDE 18 retrieves the metaproject associated with the component and initializes meta-machine 10 with the metaproject. All the metaprograms 14 in the metaproject are, in effect, loaded into meta-machine 10. Then, for each meta-class in the component, MDE 18 retrieves the class metaprograms associated with the metaproject to which the component is bound and retrieves the next class metaprogram in the metaproject.

In view of the foregoing, it can be seen that by separating architecture from application the present invention overcomes the problems and deficiencies in the prior art that have increasingly hampered efficient software development and maintenance. Using the present invention as described above, applications for software systems can be developed and maintained in a modeling language independently of architectures, and architecture-dependent aspects of software systems can be developed and maintained independently of applications. Among other advantages, this independence can allow business analysts and other non-technologists to more efficiently focus upon the applications in which they have expertise and leave the architecture-dependent metaprogramming to programmers and other technologists.

It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention

disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

CLAIMS

1. A method for developing a software system, comprising the steps of:

providing an object model expressed in an object modeling computer language, the object model representing a software system and comprising components realizing classes;

providing a set of one or more metaprograms reflecting a computer system architecture; and

a meta-machine binding the components to the metaprograms to generate the software system for a computer system having said architecture.

2. The method claimed in claim 1, wherein the object modeling computer language is the Unified Modeling Language (UML).

3. The method claimed in claim 1, wherein:

the step of providing an object model is performed in part by a business analyst creating the object model; and

the step of providing a set of one or more metaprograms is performed in part by a technologist coding the metaprograms.

4. The method claimed in claim 1, wherein:

the step of providing an object model comprises a user using a graphical user interface to list a project in a first window, the project representing the object model; and

the step of providing one or more metaprograms comprises a user using a graphical user interface to list one or more metaprojects in a second window, each metaproject including a list of representations of the metaprograms.

5. The method claimed in claim 4, wherein the object modeling computer

language includes an extension mechanism for the specification of user-defined properties and the assignment of these properties and their values to elements of the object model.

6. The method claimed in claim 5, wherein:

the object modeling computer language is the Unified Modeling Language (UML); and

the user-defined extension mechanism is a Stereootype.

7. The method claimed in claim 5, wherein:

the object modeling computer language is the Unified Modeling Language (UML); and

the user-defined extension mechanism is Tagged Values.

8. The method claimed in claim 5, wherein the step of a meta-machine binding the components to the metaprograms comprises the steps of:

searching the list of metaprojects for a metaproject having a name matching a name of an implementation target, wherein the implementation target is defined by the user-defined extension mechanism associated with the components; and

storing an indication of an association between the metaproject having the matching name with metaprograms of which representations are listed in the metaproject having the matching name.

9. The method claimed in claim 8, wherein:

the object modeling computer language is the Unified Modeling Language (UML);

the user-defined extension mechanism is a Stereootype; and

the Stereotype indicates the implementation target.

10. The method claimed in claim 8, wherein:

the object modeling computer language is the Unified Modeling Language (UML);

the user-defined extension mechanism is Tagged Values; and

the Tagged Values indicate the implementation target.

11. The method claimed in claim 1, further comprising the step of a user using a graphical user interface to invoke a metaprogram editor.

12. The method claimed in claim 1, wherein each metaprogram in said set of metaprograms includes code and metacode, and the metacode generates a portion of the source code of the software system by outputting the code.

13. The method claimed in claim 12, further comprising the step of a user using a graphical user interface to invoke a metaprogram editor.

14. The method claimed in claim 13, further comprising the step of a user activating a toggling function of the metaprogram editor to toggle a window between highlighting the code and highlighting the metacode.

15. The method claimed in claim 1, wherein the set of metaprograms includes a model metaprogram that modifies the object model.

16. The method claimed in claim 1, wherein the set of metaprograms includes a component metaprogram invoked once for each component and uses the classes realized by the component to produce a portion of the software system.

17. The method claimed in claim 1, wherein the set of metaprograms includes a class metaprogram that is invoked once for each class realized in each component and

that produces a portion of the software system.

18. A meta-development environment computer program product for developing a software system, the computer program product comprising a computer-readable medium carrying thereon:

a meta-machine responsive to an object model and a set of one or more metaprograms input to the meta-machine under control of a user, the object model expressed in an object modeling computer language, the object model representing a software system and comprising components realizing object classes, the set of metaprograms reflecting a computer system architecture, the meta-machine under control of the user binding the components to the metaprograms to generate a resultant software system executable on a computer system having the architecture; and

a user interface for providing user control of metaprogram input, object model input, meta-machine operation, and resultant software system output.

19. The computer program product claimed in claim 18, wherein the object modeling computer language is the Unified Modeling Language (UML).

20. The computer program product claimed in claim 18, wherein the user interface comprises a graphical user interface listing a project in a first window, the project representing the object model, and listing one or more metaprojects in a second window, each metaproject including a list of representations of the metaprograms.

21. The computer program product claimed in claim 20, wherein the object modeling computer language includes an extension mechanism for the specification of user-defined properties and the assignment of these properties and their values to elements of the object model.

22. The computer program product claimed in claim 21, wherein:

the object modeling computer language is the Unified Modeling Language (UML); and

the user-defined extension mechanism is a Stereootype.

23. The computer program product claimed in claim 21, wherein:

the object modeling computer language is the Unified Modeling Language (UML); and

the user-defined extension mechanism is Tagged Values.

24. The computer program product claimed in claim 21, wherein the meta-machine binds the components to the metaprograms by searching the list of metaprojects for a metaproject having a name matching a name of an implementation target and storing an indication of an association between the metaproject having the matching name with metaprograms of which representations are listed in the metaproject having the matching name, wherein the implementation target is defined by the user-defined extension mechanism associated with the components.

25. The computer program product claimed in claim 24, wherein:

the object modeling computer language is the Unified Modeling Language (UML);

the user-defined extension mechanism is a Stereotype; and

the Stereotype indicates the implementation target.

26. The computer program product claimed in claim 24, wherein:

the object modeling computer language is the Unified Modeling Language (UML);

the user-defined extension mechanism is Tagged Values; and

the Tagged Values indicate the implementation target.

27. The computer program product claimed in claim 18, wherein the user interface includes a metaprogram editor.

28. The computer program product claimed in claim 18, wherein each metaprogram in said set of metaprograms includes code and metacode, and the metacode generates a portion of the source code of the software system by outputting the code.

29. The computer program product claimed in claim 28, wherein the user interface includes a metaprogram editor.

30. The computer program product claimed in claim 29, wherein the metaprogram editor includes a toggling means for toggling a window between highlighting the code and highlighting the metacode.

31. The computer program product claimed in claim 18, wherein the set of metaprograms includes a model metaprogram that modifies the object model.

32. The computer program product claimed in claim 18, wherein the set of metaprograms includes a component metaprogram invoked once for each component and uses the classes realized by the component to produce a portion of the software system.

33. The computer program product claimed in claim 18, wherein the set of metaprograms includes a class metaprogram that is invoked once for each class realized in each component and that produces a portion of the software system.

34. A method for developing software systems for a plurality of computer system

architectures, comprising the steps of:

providing a meta-development environment (MDE) to a first party having access to a first computer system with a first architecture;

providing the MDE to a second party having access to a second computer system with a second architecture;

providing the first party's MDE with an object model expressed in an object modeling computer language, the object model representing a software system and comprising components realizing classes;

providing the second party's MDE with the object model;

providing the first party's MDE with a first set of one or more metaprograms reflecting the first architecture, wherein binding in the MDE of the components of the object model and the first set of metaprograms defines first software system code executable on a computer system having the first architecture but not executable on a computer system having the second architecture, the first software system code effecting a user application when executed on the first computer system; and

providing the second party's MDE with a second set of one or more metaprograms reflecting the second architecture, wherein binding in the MDE of the components of the object model and the second set of metaprograms defines second software system code executable on a computer system having the second architecture but not executable on a computer system having the first architecture, the second software system code effecting the same user application when executed on the second computer system as the first software system code effects when executed on the first computer system.

35. The method claimed in claim 34, wherein:

the MDE includes a metaprogram editor and a meta-machine;

the step of providing the first party's MDE with a first set of one or more metaprograms includes the step of the first party using the metaprogram editor of the first party's MDE to write metaprogram code; and

the step of providing the second party's MDE with a second set of one or more metaprograms includes the step of the second party using the metaprogram editor of the second party's MDE to write metaprogram code.

36. The method claimed in claim 35, wherein the object modeling computer language is the Unified Modeling Language (UML).

37. The method claimed in claim 35, wherein:

the step of providing the first party's MDE with an object model comprises the first party purchasing the object model from a vendor and loading the object model into the first party's MDE; and

the step of providing the second party's MDE with an object model comprises the second party purchasing the same object model from a vendor and loading the object model into the second party's MDE.

38. A method for developing software systems for a plurality of computer system architectures, comprising the steps of:

providing a meta-development environment (MDE) to a first party having access to a first computer system having an architecture;

providing the MDE to a second party having access to a second computer system having the architecture;

the first party writing a first object model expressed in an object modeling computer language and loading the first object model into the first party's MDE, the object model representing a first software system and comprising components realizing classes;

the second party writing a second object model expressed in an object modeling computer language and loading the second object model into the second party's MDE, the object model representing a second software system and comprising components realizing classes;

the first party purchasing from a vendor a set of one or more metaprograms reflecting the architecture and loading the set of metaprograms into the first party's MDE, wherein binding in the MDE of the components of the first object model and the set of metaprograms defines first software system code executable on a computer system having the architecture but not executable on a computer system having another architecture, the first software system code effecting a first user application when executed on the first computer system; and

the second party purchasing from a vendor a set of one or more metaprograms reflecting the architecture and loading the set of metaprograms into the second party's MDE, wherein binding in the MDE of the components of the second object model and the set of metaprograms defines second software system code executable on a computer system having the architecture but not executable on a computer system having another architecture, the second software system code effecting a second user application when executed on the second computer system different from that which the first software system code effects when executed on the first computer system.

39. The method claimed in claim 38, wherein the object modeling computer language is the Unified Modeling Language (UML).

40. The method claimed in claim 38, wherein:

the step of the first party writing a first object model comprises a business analyst writing the first object model; and

the step of the second party writing a second object model comprises a business analyst writing the second object model.

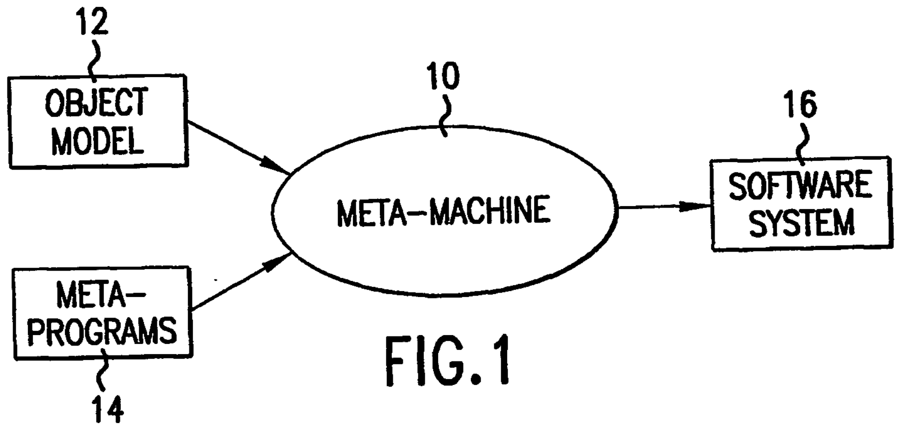

12
OBJECT MODEL
10
META-MACHINE
16
SOFTWARE SYSTEM
META-PROGRAMS
14

FIG.1

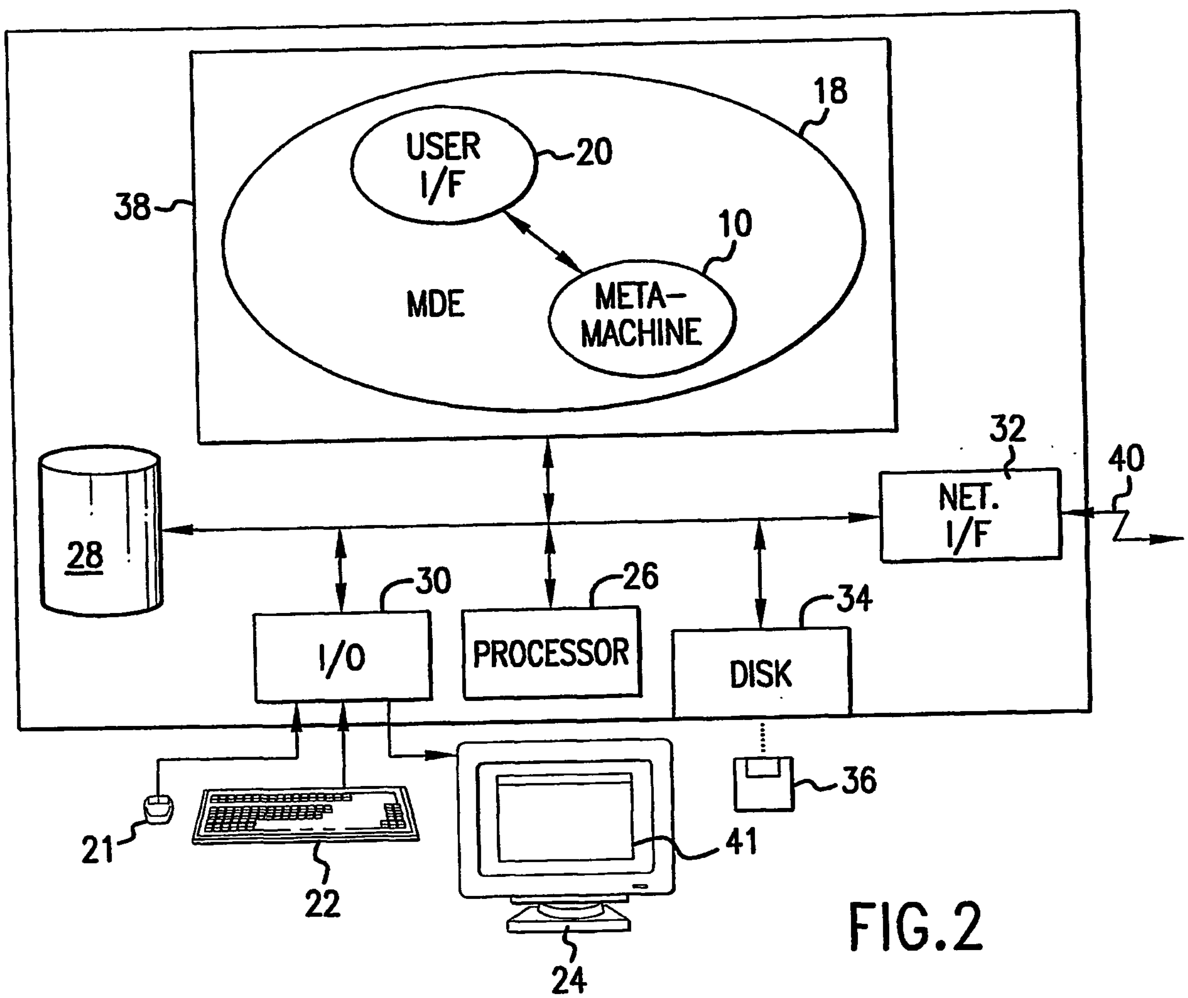

18
USER I/F
20
38
10
MDE
META-MACHINE
32
40
NET. I/F
28
30
26
34
I/O
PROCESSOR
DISK
36
21
41
22
24

FIG.2

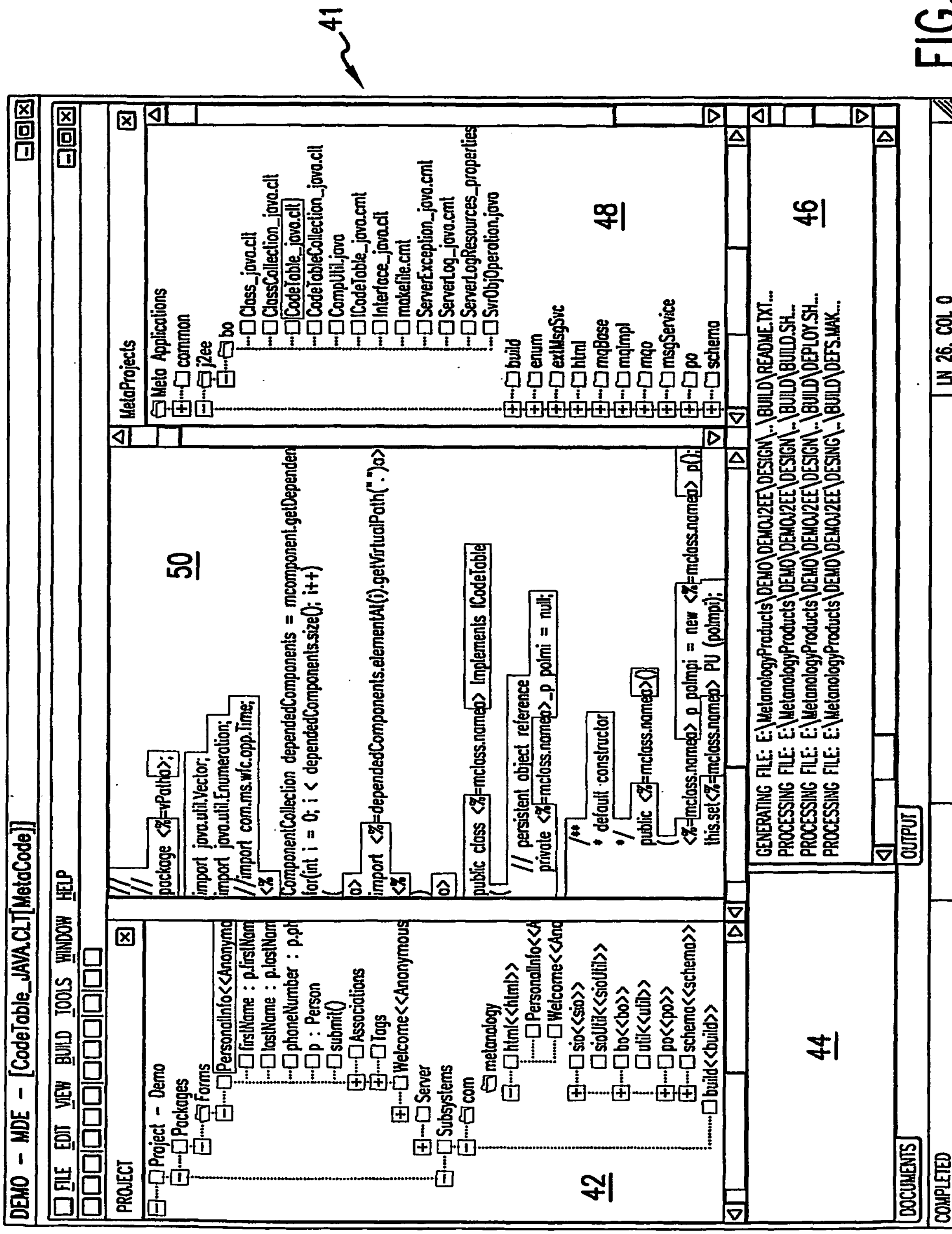

41
DEMO - MDE - [CodeTable_JAVA.CLT[MetaCode]]
FILE EDIT VIEW BUILD TOOLS WINDOW HELP
PROJECT
Project - Demo
Packages
Forms
PersonalInfo<<Anonymo
firstName : p.firstNam
lastName : p.lastNam
phoneNumber : p.ph
p : Person
submit()
Associations
Tags
Welcome<<Anonymous
Server
Subsystems
com
metanology
html<<html>>
PersonalInfo<<A
Welcome<<Ano
sio<<sio>>
sioUtil<<sioUtil>>
bo<<bo>>
util<<util>>
po<<po>>
schema<<schema>>
build<<build>>
42
44
//
//
package <%=vPath%>;
import java.util.Vector;
import java.util.Enumeration;
//import com.ms.wfc.app.Time;
<%
ComponentCollection dependedComponents = mcomponent.getDependen
for(int i = 0; i < dependedComponents.size(); i++)
import <%=dependedComponents.elementAt(i).getVirtualPath(".")%>
<%
public class <%=mclass.name%> Implements ICodeTable
{
// persistent object reference
private <%=mclass.name%>_p polmi = null;
/**
* default constructor
*/
public <%=mclass.name%>()
{
<%=mclass.name%>_p polmpi = new <%=mclass.name%>_p();
this.set<%=mclass.name%> PU (polmpi);
50
MetaProjects
Meta Applications
common
j2ee
bo
Class_java.clt
ClassCollection_java.clt
CodeTable_java.clt
CodeTableCollection_java.clt
CompUtil.java
ICodeTable_java.cmt
Interface_java.clt
makefile.cmt
ServerException_java.cmt
ServerLog_java.cmt
ServerLogResources_properties
SvrObjOperation.java
build
enum
extMsgSvc
html
mqBase
mqImpl
mqo
msgService
po
schema
48
GENERATING FILE: E:\MetanologyProducts\DEMO\DEMOJ2EE\DESIGN\..\BUILD\README.TXT...
PROCESSING FILE: E:\MetanologyProducts\DEMO\DEMOJ2EE\DESIGN\..\BUILD\BUILD.SH...
PROCESSING FILE: E:\MetanologyProducts\DEMO\DEMOJ2EE\DESIGN\..\BUILD\DEPLOY.SH...
PROCESSING FILE: E:\MetanologyProducts\DEMO\DEMOJ2EE\DESING\..\BUILD\DEFS.MAK...
46
DOCUMENTS
OUTPUT
COMPLETED
LN 26, COL 0

FIG.3

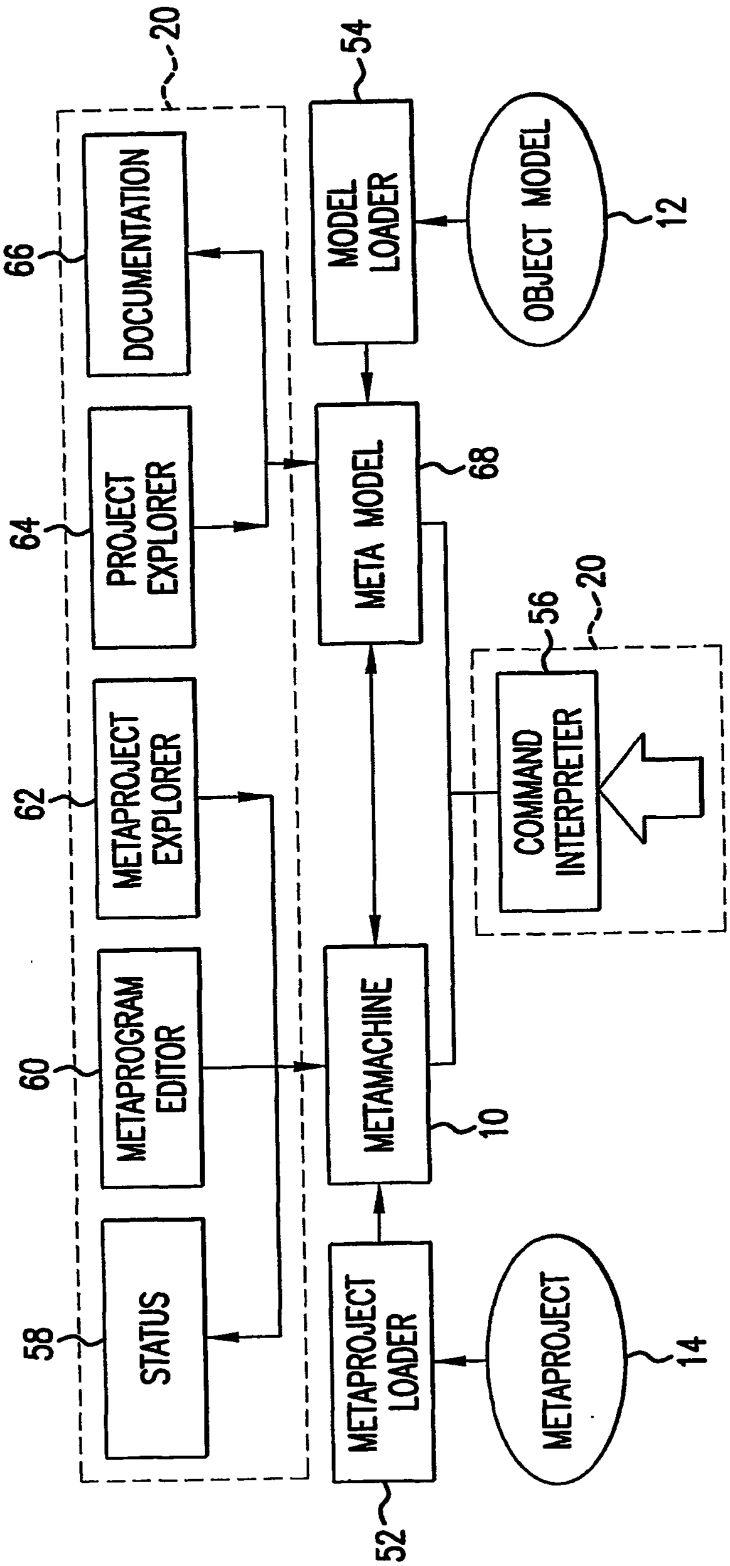

20
DOCUMENTATION
66
PROJECT EXPLORER
64
METAPROJECT EXPLORER
62
METAPROGRAM EDITOR
60
STATUS
58
MODEL LOADER
54
META MODEL
68
METAMACHINE
10
METAPROJECT LOADER
52
OBJECT MODEL
12
COMMAND INTERPRETER
56
20
METAPROJECT
14

FIG.4

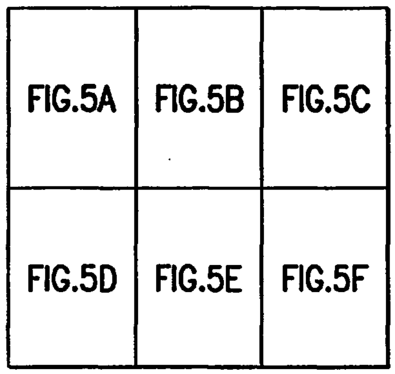
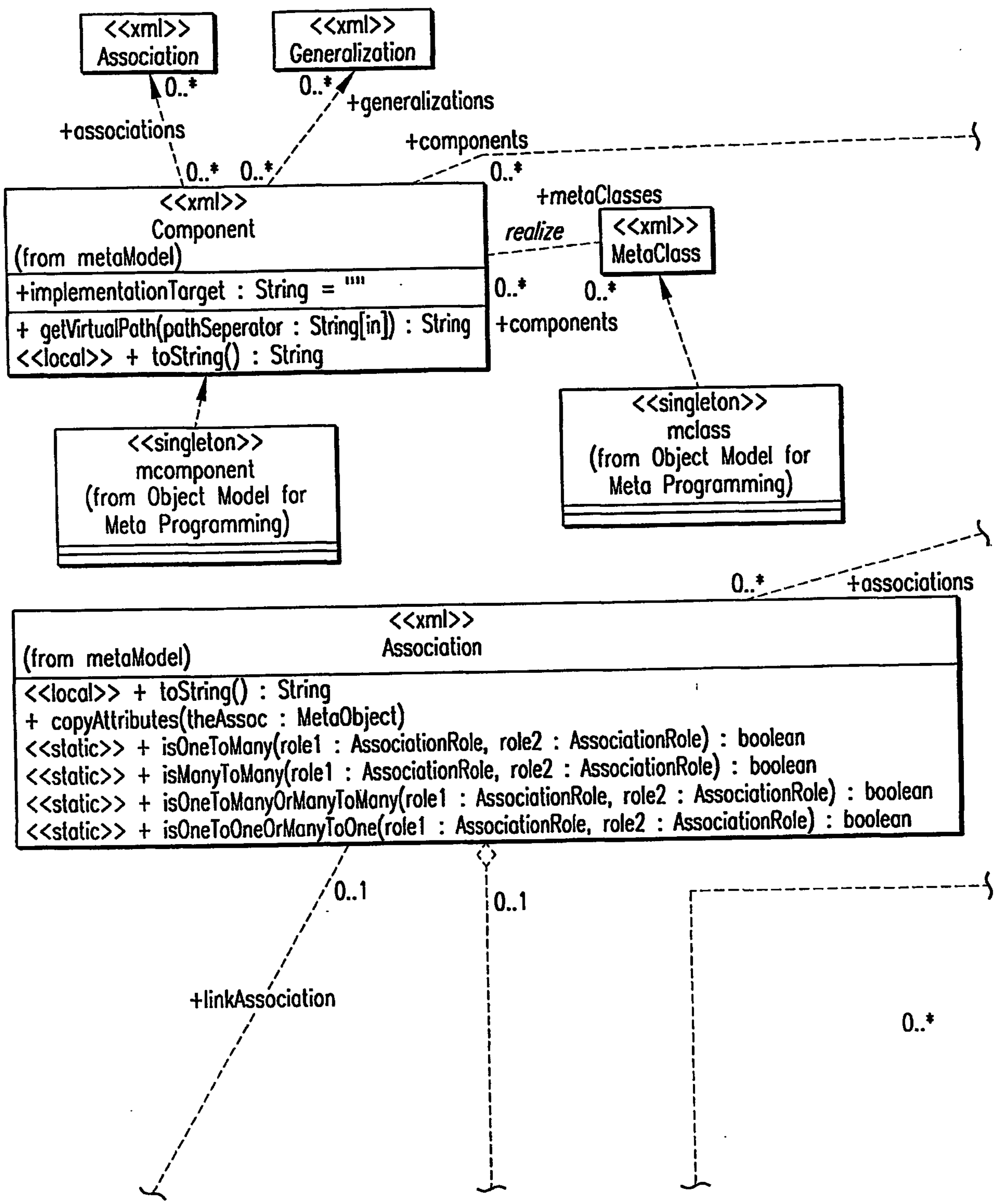
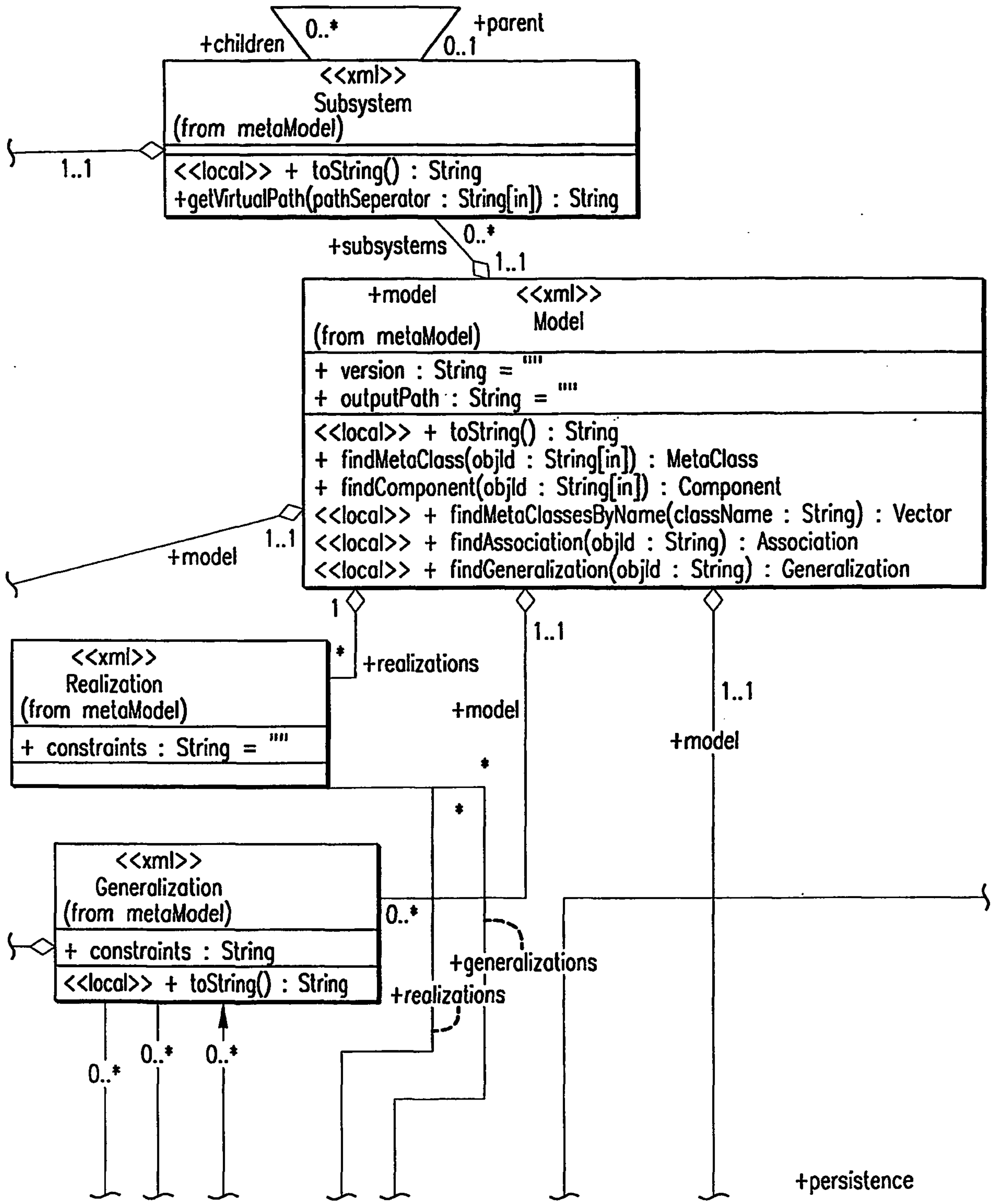


FIG.5



<<xml>>
Association
<<xml>>
Generalization
0..*
0..*
+generalizations
+associations
0..*
0..*
+components
0..*
+metaClasses
realize
<<xml>>
MetaClass
<<xml>>
Component
(from metaModel)
+implementationTarget : String = ""
+ getVirtualPath(pathSeperator : String[in]) : String
<<local>> + toString() : String
0..*
0..*
+components
<<singleton>>
mcomponent
(from Object Model for
Meta Programming)
<<singleton>>
mclass
(from Object Model for
Meta Programming)
0..*
+associations
<<xml>>
Association
(from metaModel)
<<local>> + toString() : String
+ copyAttributes(theAssoc : MetaObject)
<<static>> + isOneToMany(role1 : AssociationRole, role2 : AssociationRole) : boolean
<<static>> + isManyToMany(role1 : AssociationRole, role2 : AssociationRole) : boolean
<<static>> + isOneToManyOrManyToMany(role1 : AssociationRole, role2 : AssociationRole) : boolean
<<static>> + isOneToOneOrManyToOne(role1 : AssociationRole, role2 : AssociationRole) : boolean
0..1
0..1
+linkAssociation
0..*

FIG. 5A



+children
0..*
+parent
0..1
<<xml>>
Subsystem
(from metaModel)
1..1
<<local>> + toString() : String
+getVirtualPath(pathSeperator : String[in]) : String
+subsystems
0..*
1..1
+model
<<xml>>
Model
(from metaModel)
+ version : String = ""
+ outputPath : String = ""
<<local>> + toString() : String
+ findMetaClass(objId : String[in]) : MetaClass
+ findComponent(objId : String[in]) : Component
<<local>> + findMetaClassesByName(className : String) : Vector
<<local>> + findAssociation(objId : String) : Association
<<local>> + findGeneralization(objId : String) : Generalization
1..1
+model
1
*
+realizations
1..1
+model
1..1
+model
<<xml>>
Realization
(from metaModel)
+ constraints : String = ""
*
*
<<xml>>
Generalization
(from metaModel)
+ constraints : String
<<local>> + toString() : String
0..*
+generalizations
+realizations
0..*
0..*
0..*
+persistence

FIG. 5B

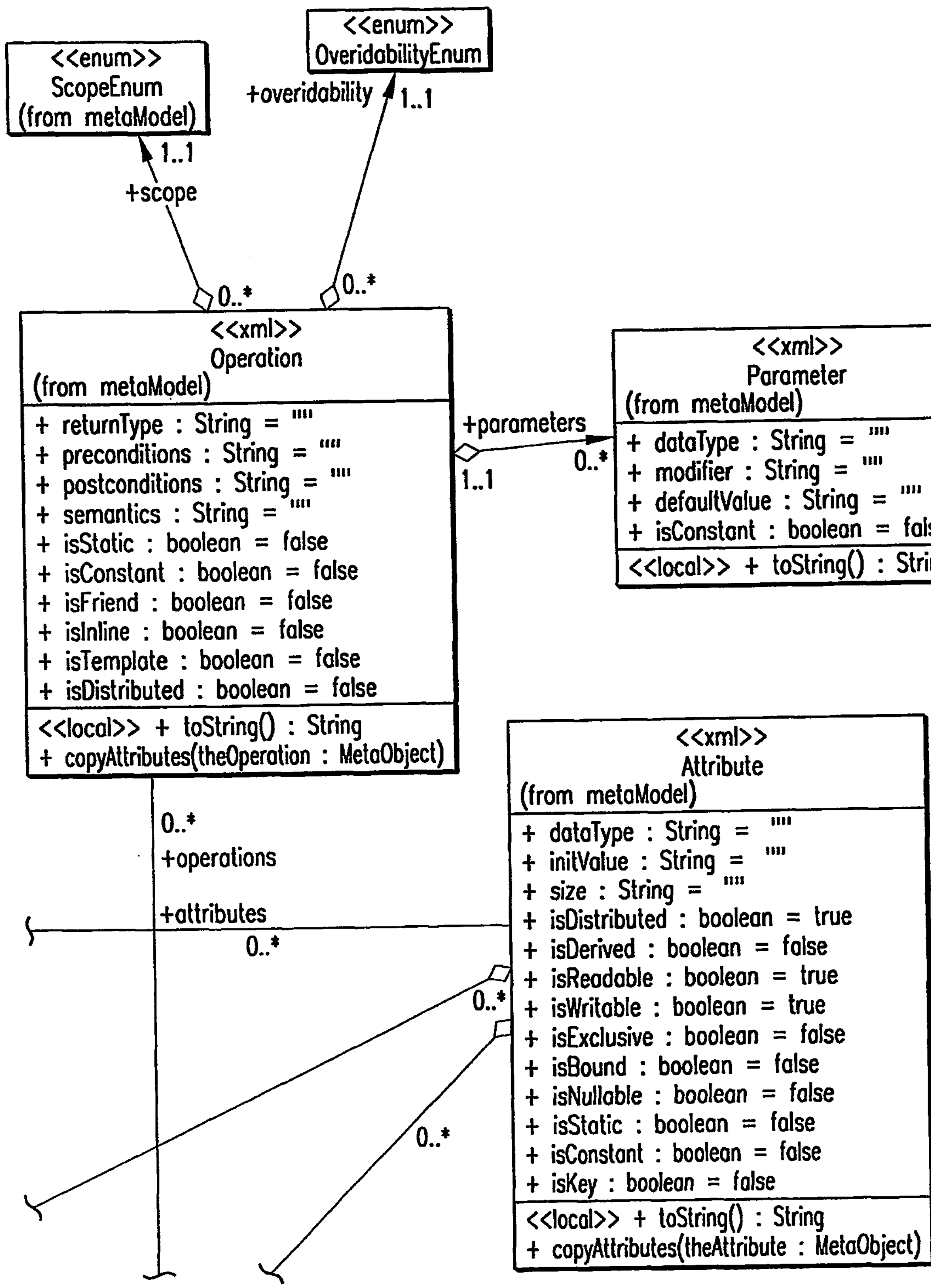
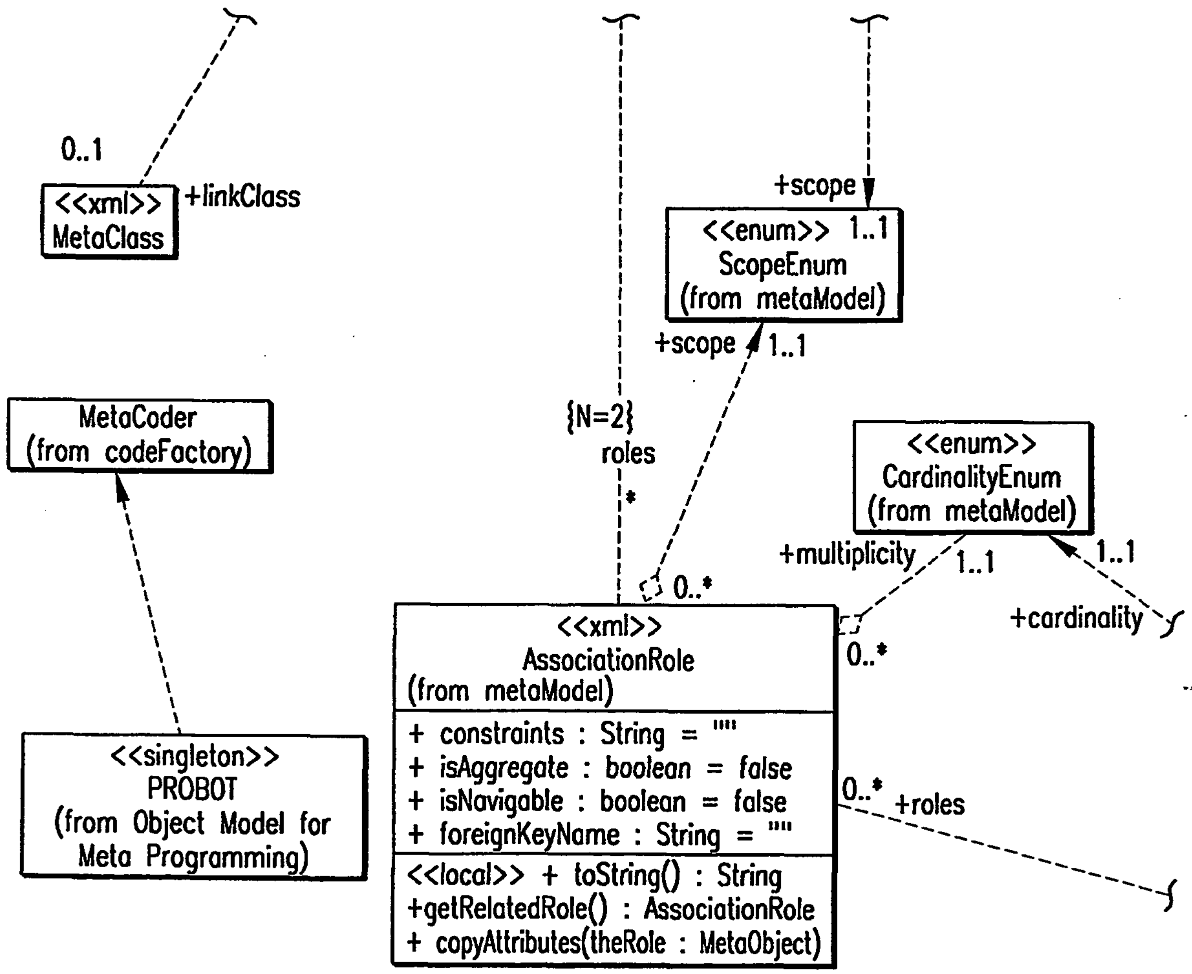

<<enum>>
ScopeEnum
(from metaModel)
<<enum>>
OveridabilityEnum
+overidability
1..1
1..1
+scope
0..*
0..*
<<xml>>
Operation
(from metaModel)
+ returnType : String = ""
+ preconditions : String = ""
+ postconditions : String = ""
+ semantics : String = ""
+ isStatic : boolean = false
+ isConstant : boolean = false
+ isFriend : boolean = false
+ isInline : boolean = false
+ isTemplate : boolean = false
+ isDistributed : boolean = false
<<local>> + toString() : String
+ copyAttributes(theOperation : MetaObject)
+parameters
0..*
1..1
<<xml>>
Parameter
(from metaModel)
+ dataType : String = ""
+ modifier : String = ""
+ defaultValue : String = ""
+ isConstant : boolean = false
<<local>> + toString() : String
0..*
+operations
+attributes
0..*
0..*
0..*
<<xml>>
Attribute
(from metaModel)
+ dataType : String = ""
+ initValue : String = ""
+ size : String = ""
+ isDistributed : boolean = true
+ isDerived : boolean = false
+ isReadable : boolean = true
+ isWritable : boolean = true
+ isExclusive : boolean = false
+ isBound : boolean = false
+ isNullable : boolean = false
+ isStatic : boolean = false
+ isConstant : boolean = false
+ isKey : boolean = false
<<local>> + toString() : String
+ copyAttributes(theAttribute : MetaObject)

FIG. 5C



0..1
<<xml>>
MetaClass
+linkClass
+scope
<<enum>> 1..1
ScopeEnum
(from metaModel)
+scope
1..1
MetaCoder
(from codeFactory)
{N=2}
roles
*
<<enum>>
CardinalityEnum
(from metaModel)
+multiplicity
1..1
1..1
0..*
+cardinality
<<xml>>
AssociationRole
(from metaModel)
+ constraints : String = ""
+ isAggregate : boolean = false
+ isNavigable : boolean = false
+ foreignKeyName : String = ""
<<local>> + toString() : String
+getRelatedRole() : AssociationRole
+ copyAttributes(theRole : MetaObject)
0..*
0..*
+roles
<<singleton>>
PROBOT
(from Object Model for
Meta Programming)

FIG. 5D

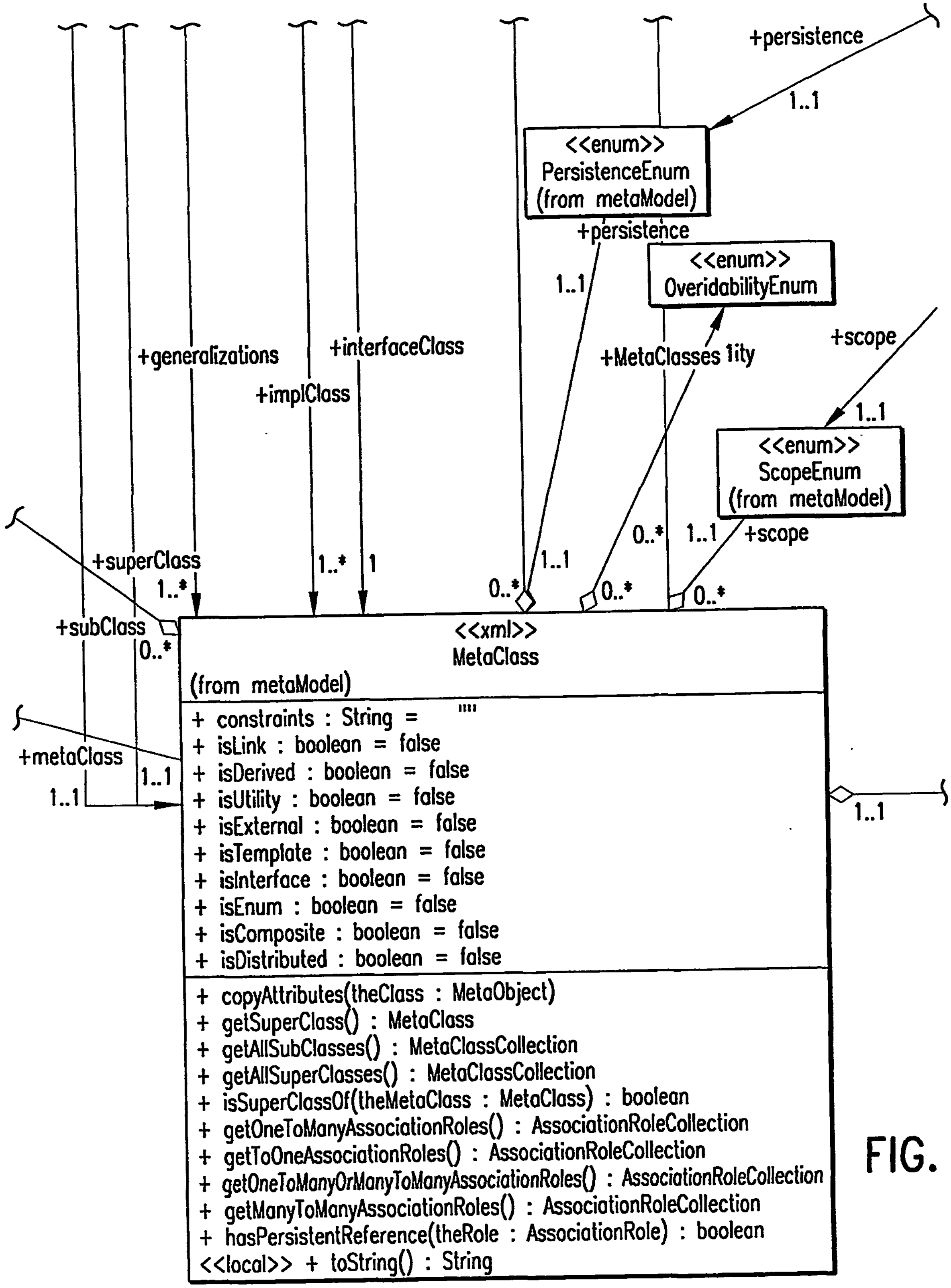

+persistence
1..1
<<enum>>
PersistenceEnum
(from metaModel)
+persistence
1..1
<<enum>>
OveridabilityEnum
+generalizations
+interfaceClass
+implClass
+MetaClasses 1ity
+scope
1..1
<<enum>>
ScopeEnum
(from metaModel)
0..* 1..1 +scope
+superClass
1..* 1..* 1
0..* 1..1
0..*
0..*
+subClass
0..*
<<xml>>
MetaClass
(from metaModel)
+ constraints : String = ""
+ isLink : boolean = false
+ isDerived : boolean = false
+ isUtility : boolean = false
+ isExternal : boolean = false
+ isTemplate : boolean = false
+ isInterface : boolean = false
+ isEnum : boolean = false
+ isComposite : boolean = false
+ isDistributed : boolean = false
+ copyAttributes(theClass : MetaObject)
+ getSuperClass() : MetaClass
+ getAllSubClasses() : MetaClassCollection
+ getAllSuperClasses() : MetaClassCollection
+ isSuperClassOf(theMetaClass : MetaClass) : boolean
+ getOneToManyAssociationRoles() : AssociationRoleCollection
+ getToOneAssociationRoles() : AssociationRoleCollection
+ getOneToManyOrManyToManyAssociationRoles() : AssociationRoleCollection
+ getManyToManyAssociationRoles() : AssociationRoleCollection
+ hasPersistentReference(theRole : AssociationRole) : boolean
<<local>> + toString() : String
+metaClass
1..1
1..1
1..1

FIG. 5E

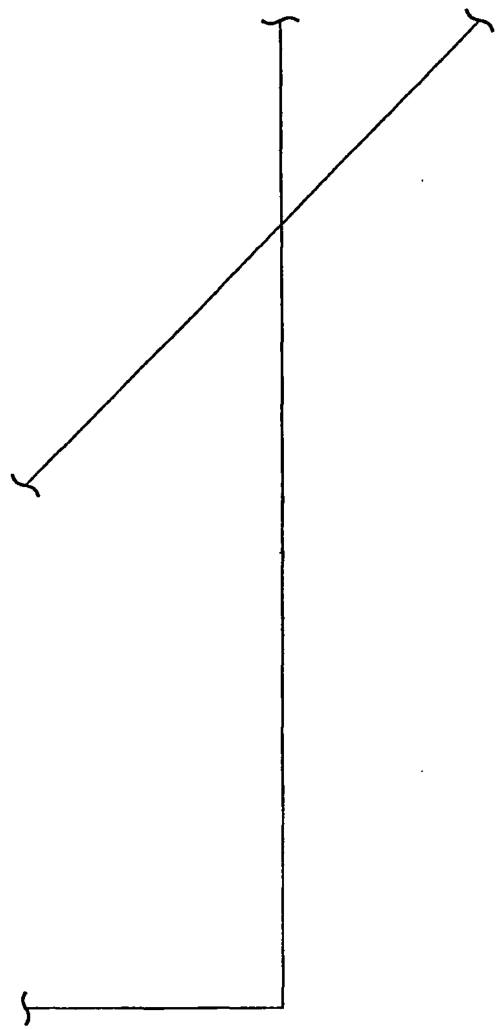
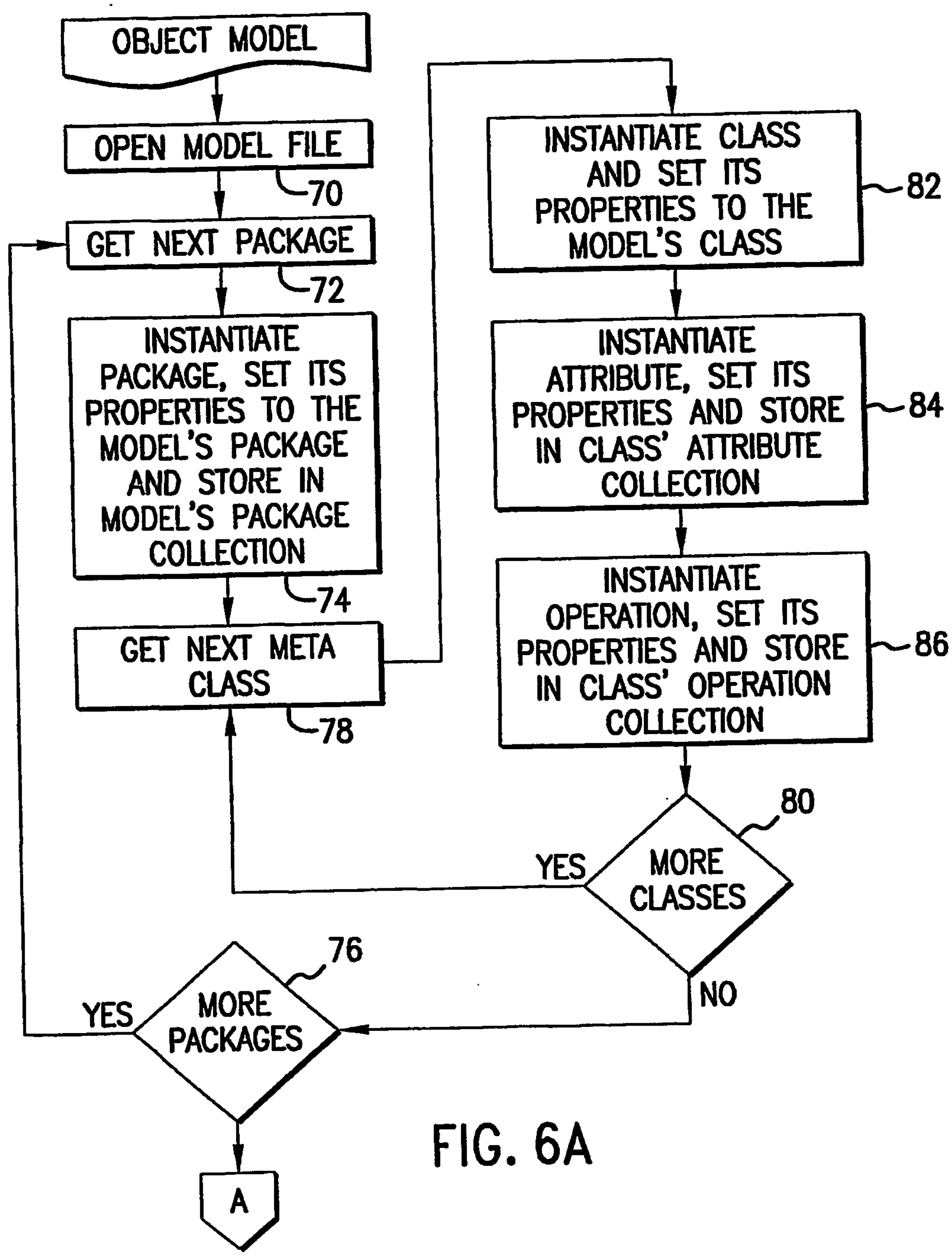


FIG. 5F



OBJECT MODEL
OPEN MODEL FILE
70
GET NEXT PACKAGE
72
INSTANTIATE PACKAGE, SET ITS PROPERTIES TO THE MODEL'S PACKAGE AND STORE IN MODEL'S PACKAGE COLLECTION
74
GET NEXT META CLASS
78
INSTANTIATE CLASS AND SET ITS PROPERTIES TO THE MODEL'S CLASS
82
INSTANTIATE ATTRIBUTE, SET ITS PROPERTIES AND STORE IN CLASS' ATTRIBUTE COLLECTION
84
INSTANTIATE OPERATION, SET ITS PROPERTIES AND STORE IN CLASS' OPERATION COLLECTION
86
80
MORE CLASSES
YES
NO
76
MORE PACKAGES
YES
A

FIG. 6A

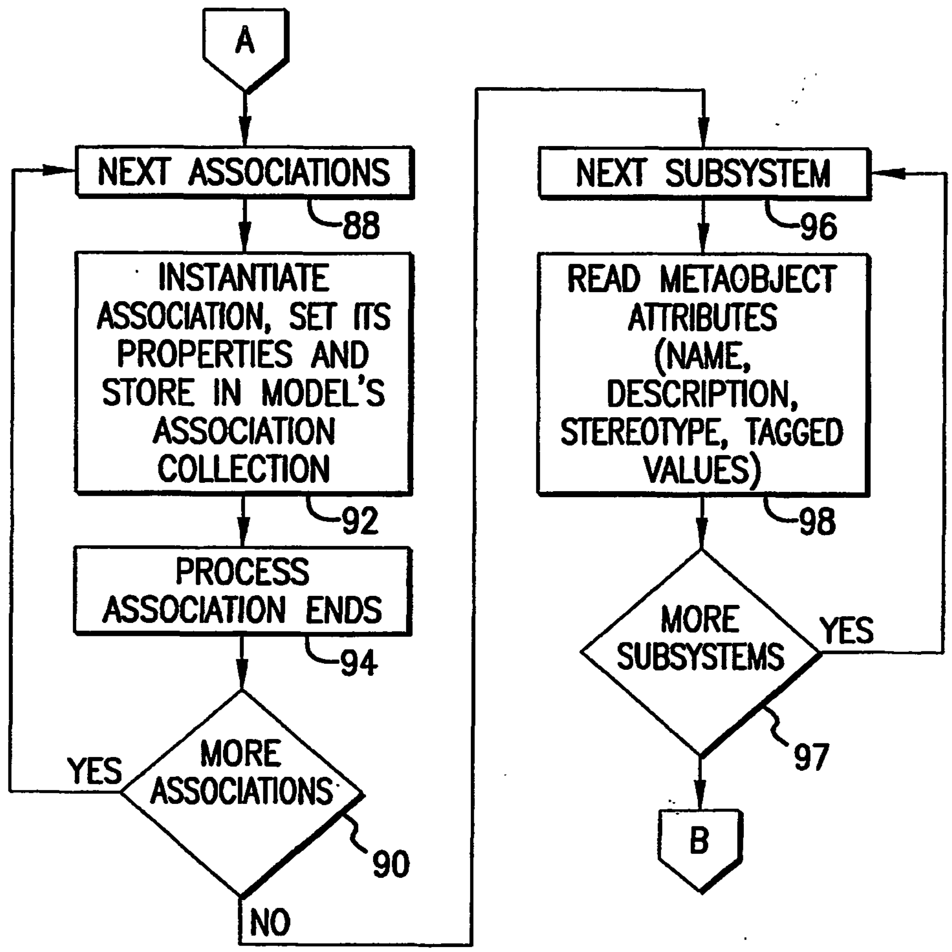

A
NEXT ASSOCIATIONS
88
INSTANTIATE ASSOCIATION, SET ITS PROPERTIES AND STORE IN MODEL'S ASSOCIATION COLLECTION
92
PROCESS ASSOCIATION ENDS
94
MORE ASSOCIATIONS
YES
NO
90
NEXT SUBSYSTEM
96
READ METAOBJECT ATTRIBUTES (NAME, DESCRIPTION, STEREOTYPE, TAGGED VALUES)
98
MORE SUBSYSTEMS
YES
97
B

FIG.6B

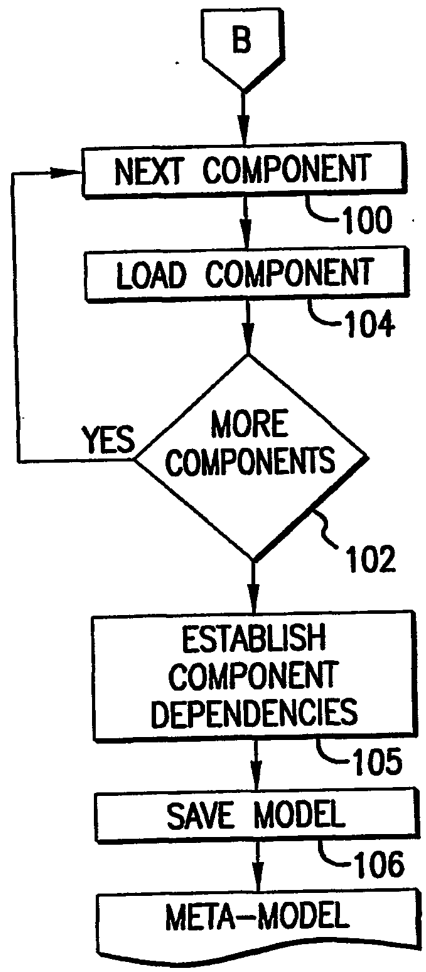

B
NEXT COMPONENT
100
LOAD COMPONENT
104
MORE COMPONENTS
YES
102
ESTABLISH COMPONENT DEPENDENCIES
105
SAVE MODEL
106
META-MODEL

FIG.6C

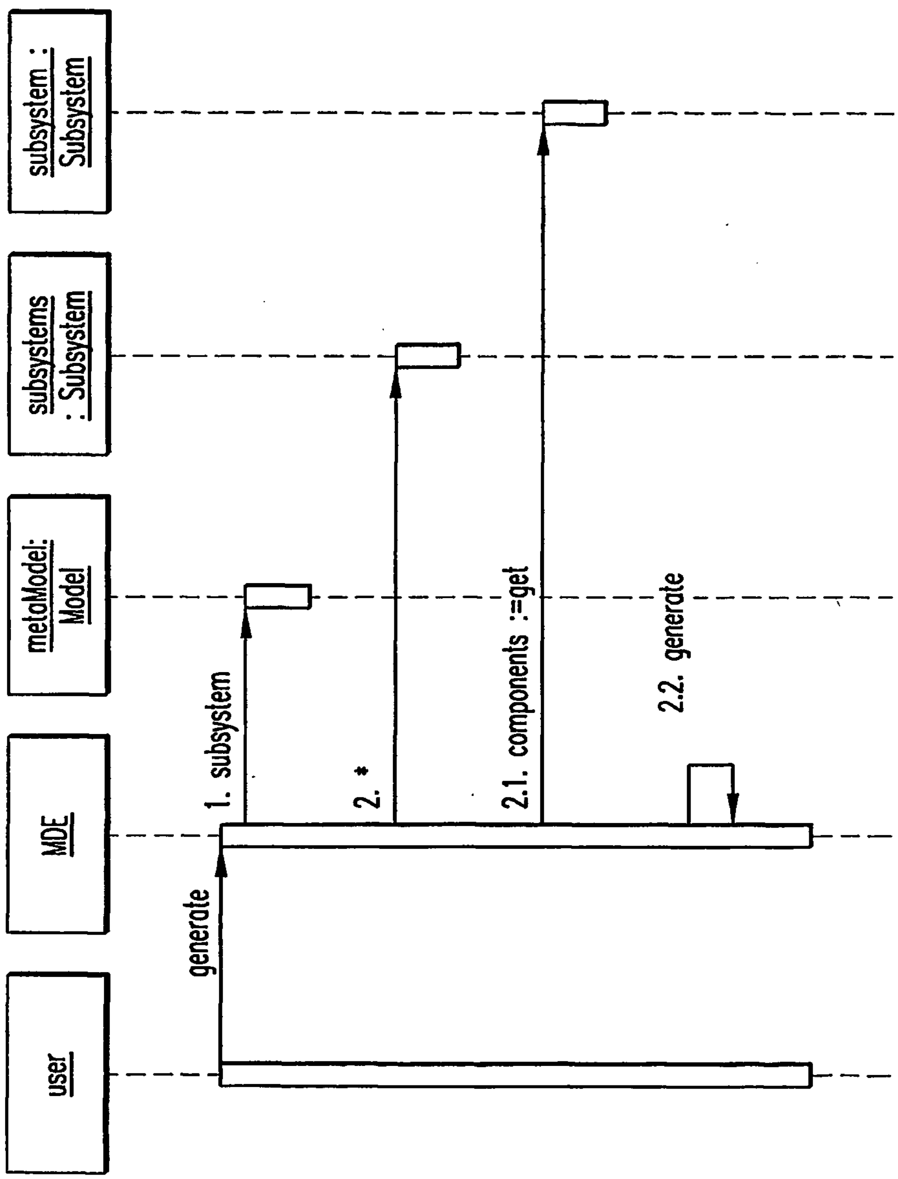

subsystem :
Subsystem
subsystems
: Subsystem
metaModel:
Model
MDE
user
generate
1. subsystem
2. *
2.1. components :=get
2.2. generate

FIG.7

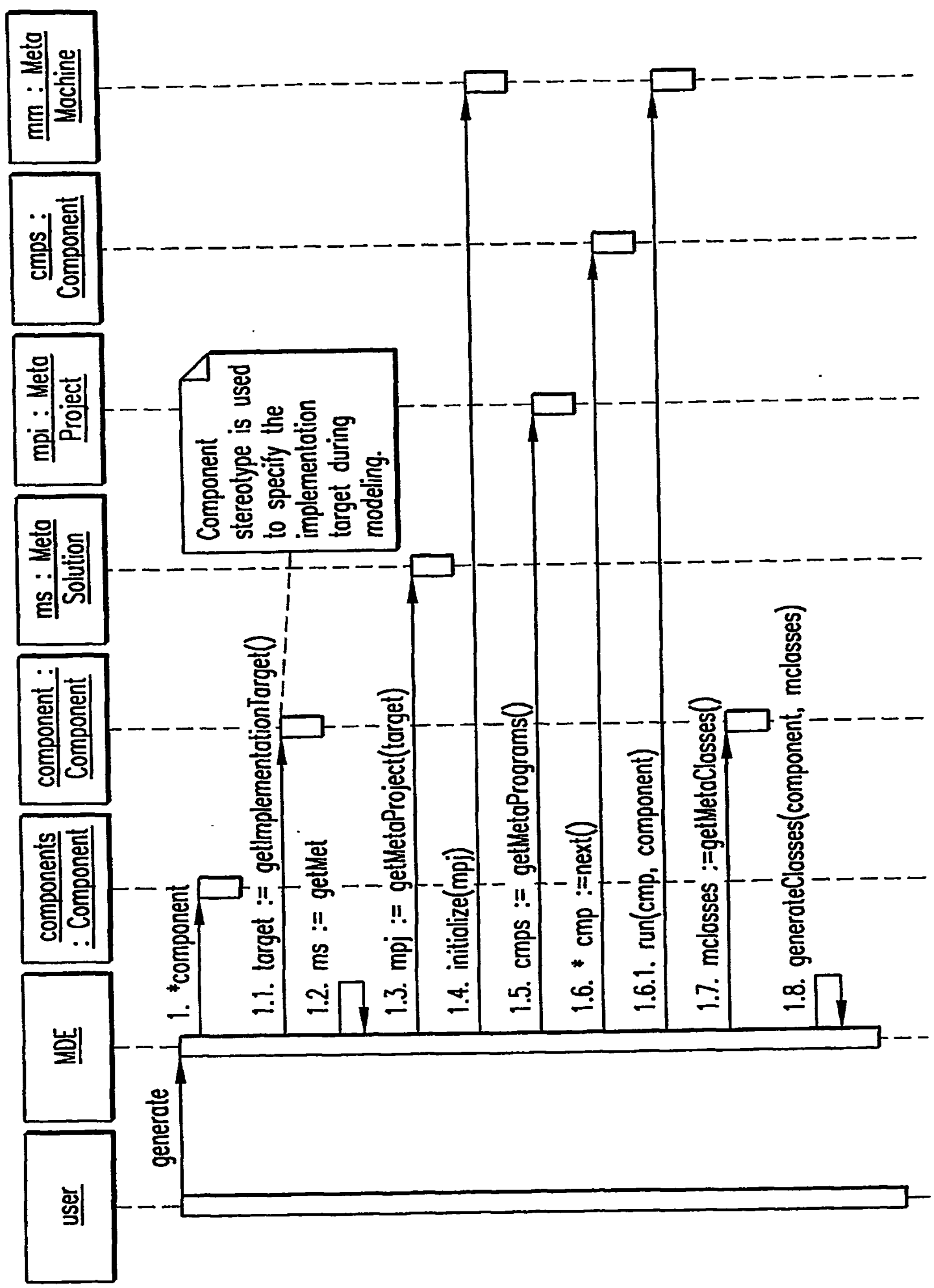
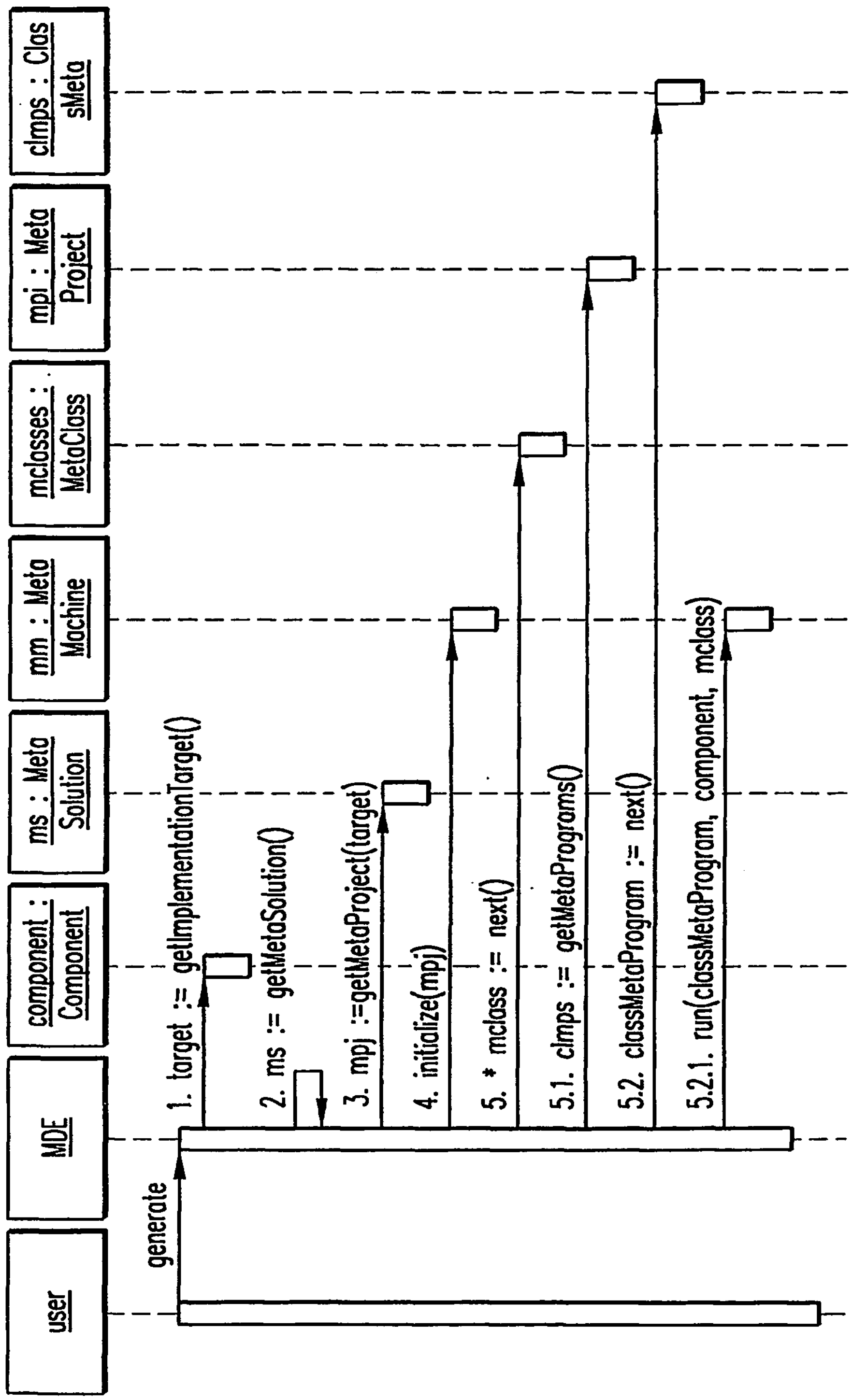

user
MDE
components : Component
component : Component
ms : Meta Solution
mpi : Meta Project
cmps : Component
mm : Meta Machine
Component stereotype is used to specify the implementation target during modeling.
generate
1. *component
1.1. target := getImplementationTarget()
1.2. ms := getMet
1.3. mpj := getMetaProject(target)
1.4. initialize(mpj)
1.5. cmps := getMetaPrograms()
1.6. * cmp :=next()
1.6.1. run(cmp, component)
1.7. mclasses :=getMetaClasses()
1.8. generateClasses(component, mclasses)

FIG.8



user
MDE
component : Component
ms : MetaSolution
mm : MetaMachine
mclasses : MetaClass
mpi : MetaProject
clmps : ClassMeta
generate
1. target := getImplementationTarget()
2. ms := getMetaSolution()
3. mpj :=getMetaProject(target)
4. initialize(mpj)
5. * mclass := next()
5.1. clmps := getMetaPrograms()
5.2. classMetaProgram := next()
5.2.1. run(classMetaProgram, component, mclass)

FIG.9

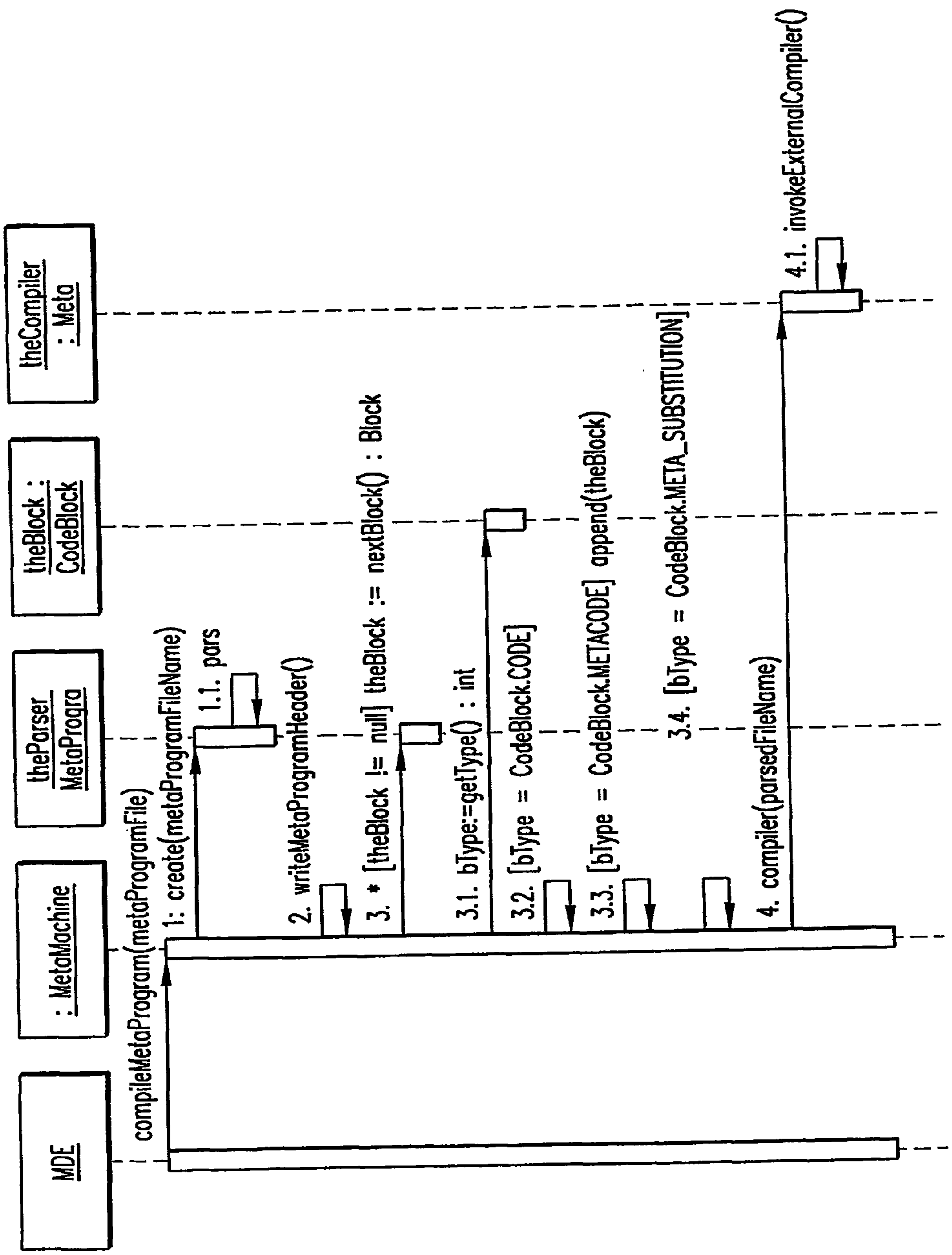

MDE
: MetaMachine
theParser
MetaProgra
theBlock :
CodeBlock
theCompiler
: Meta
compileMetaProgram(metaProgramFile)
1: create(metaProgramFileName)
1.1. pars
2. writeMetaProgramHeader()
3. * [theBlock != null] theBlock := nextBlock() : Block
3.1. bType:=getType() : int
3.2. [bType = CodeBlock.CODE]
3.3. [bType = CodeBlock.METACODE] append(theBlock)
3.4. [bType = CodeBlock.META_SUBSTITUTION]
4. compiler(parsedFileName)
4.1. invokeExternalCompiler()

FIG.10

SYSTEM ENUMERATIONS

PersistenceEnum

CONTAINS ENUMERATIONS FOR THE PERSISTENCY OF MODEL ELEMENTS IN AN OBJECT MODELING LANGUAGE.

NAME	VALUE	DESCRIPTION
PERSISTENT	15	INDICATES A PERSISTENT MODEL ELEMENT.
TRANSIENT	16	INDICATES A TRASIENT MODEL ELEMENT.

ScopeEnum

CONTAINS ENUMERATIONS FOR THE SCOPE A MODEL ELEMENT MAY HAVE IN AN OBJECT MODELING LANGUAGE.

NAME	VALUE	DESCRIPTION
PUBLIC	11	INDICATES PUBLIC SCOPE.
PROTECTED	12	INDICATES PROTECTED SCOPE.
PRIVATE	13	INDICATES PRIVATE SCOPE.
IMPLEMENTATION	14	INDICATES IMPLEMENTATION SCOPE.

CardinalityEnum

CONTAINS ENUMERATIONS FOR THE MULTIPLICITY OF AN ASSOCIATION IN AN OBJECT MODELING LANGUAGE.

NAME	VALUE	DESCRIPTION
EXACTLY_ONE	1	INDICATES A MULTIPLICITY OF ONE (REQUIRED).
MANY	2	INDICATES A MULTIPLICITY OF MANY (E.G., * OR M..N).
OPTIONAL	3	INDICATES OPTIONAL MULTIPLICITY (E.G., 0, 0..N).
ONE_OR_MORE	4	INDICATES MULTIPLICITY OF AT LEAST ONE (E.G., 1, 1..N).
ZERO_OR_MORE	5	INDICATES OPTIONAL MULTIPLICITY (E.G., 0..N).

OveridabilityEnum

CONTAINS ENUMERATIONS FOR THE CONDITIONS OF A MODEL ELEMENT THAT ALLOW THE MODEL ELEMENT TO BE OVERRIDDEN.

NAME	VALUE	DESCRIPTION
VIRTUAL	6	INDICATES A VIRTUAL MODEL ELEMENT.
LEAF	7	INDICATES A CLASS IN A LEAF IS AN INHERITANCE HIERARCHY.
ABSTRACT	8	INDICATES THE MODEL ELEMENT IS ABSTRACT.
CONCRETE	9	INDICATES THE CLASS IS CONCRETE.
EXTENSIBLE	10	INDICATES THE MODEL ELEMENT CAN BE EXTENDED (INHERITED FROM).

FIG. 11A

ContainmentEnum

CONTAINS ENUMERATIONS FOR THE DIFFERENT CONTAINMENT MECHANISMS BETWEEN MODEL ELEMENTS IN AN OBJECT MODELING LANGUAGE.

NAME	VALUE	DESCRIPTION
VALUE	20	INDICATES CONTAINMENT BY VALUE.
REFERENCE	21	INDICATES CONTAINMENT BY REFERENCE.
UNKNOWN_CONTAINMENT	22	INDICATES UNKNOWN CONTAINMENT METHOD.

FIG. 11B

Class Attribute

FIG.12A

```
Object
  |
  +---MetaObject
      |
      +---Attribute
```

public class Attribute
extends MetaObject

DESCRIPTION

AN ATTRIBUTE INSTANCE REPRESENTS AN ATTRIBUTE OF A CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM.

PROPERTIES

NAME	TYPE	DESCRIPTION
dataType	STRING	THE DATA TYPE OF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE.
initValue	STRING	THE INITIAL VALUE OF THE ATTRIBUTE IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE.
size	STRING	THE SIZE OF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE.
isDistributed	BOOLEAN	DEPRICATED. TRUE IF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE IS DISTRIBUTED. THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE ARE USED TO PROVIDE THE INDICATION.
isDerived	BOOLEAN	TRUE IF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE IS DERIVED.
isReadable	BOOLEAN	TRUE IF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE IS READABLE. THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE PROVIDE THE INDICATION.
isWritable	BOOLEAN	TRUE IF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE IS WRITEABLE. THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE PROVIDE THE INDICATION.
isExclusive	BOOLEAN	DEPRICATED. TRUE IF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE IS EXCLUSIVE. THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE PROVIDE THE INDICATION.
isBound	BOOLEAN	DEPRICATED. TRUE IF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS.

FIG.12B

		ATTRIBUTE IS BOUND. THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE PROVIDE THE INDICATION.
isNullable	BOOLEAN	TRUE IF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE IS NULLABLE. THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE PROVIDE THE INDICATION.
isStatic	BOOLEAN	TRUE IF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE IS STATIC. STATIC ATTRIBUTES HAVE CLASS SCOPE. OFTEN, THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE PROVIDE THE INICATION.
isConstant	BOOLEAN	TRUE IF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE IS CONSTANT. THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE PROVIDE THE INDICATION.
isKey	BOOLEAN	TRUE IF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE IS A KEY. A KEY IS USED TO UNIQUELY IDENTIFY OBJECTS OF THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THE MetaClass INSTANCE THAT CONTAINS THIS ATTRIBUTE. THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE PROVIDE THE INDICATION.
scope	INT - VALUES DEFINED IN CLASS ScopeEnum	INDICATES THE SCOPE OF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE.
persistence	INT - VALUES DEFINED IN CLASS PersistenceEnum	INDICATES THE PERSISTENCE OF THE ATTRIBUTE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS ATTRIBUTE.

CONSTRUCTORS

NAME	DESCRIPTION
Attribute()	CONSTRUCTS AN EMPTY ATTRIBUTE OBJECT.

ACCESSORS/MUTATORS

NAME	DESCRIPTION
getDataType()	RETURN THE VALUE OF THE dataType PROPERTY.
setDataType(String)	SET THE VALUE OF THE DataType PROPERTY.
getInitValue()	RETURN THE VALUE OF THE initValue PROPERTY.
setInitValue(String)	SET THE VALUE OF THE initValue PROPERTY.
getSize()	RETURN THE VALUE OF THE SIZE PROPERTY.
setSize(String)	SET THE VALUE OF THE SIZE PROPERTY.
getIsDistributed()	RETURN THE VALUE OF THE isDistributed PROPERTY.
setIsDistributed(String)	SET THE VALUE OF THE isDistributed PROPERTY.
getIsDerived()	RETURN THE VALUE OF THE isDerived PROPERTY.
setIsDerived(String)	SET THE VALUE OF THE isDerived PROPERTY.

getIsReadable()	RETURN THE VALUE OF THE IsReadable PROPERTY.
setIsReadable(String)	SET THE VALUE OF THE IsReadable PROPERTY.
getIsWritable()	RETURN THE VALUE OF THE IsWritable PROPERTY.
setIsWritable(String)	SET THE VALUE OF THE IsWritable PROPERTY.
getIsExclusive()	RETURN THE VALUE OF THE IsExclusive PROPERTY.
setIsExclusive(String)	SET THE VALUE OF THE IsExclusive PROPERTY.
getIsBound()	RETURN THE VALUE OF THE IsBound PROPERTY.
setIsBound(String)	SET THE VALUE OF THE IsBound PROPERTY.
getIsNullable()	RETURN THE VALUE OF THE IsNullable PROPERTY.
setIsNullable(String)	SET THE VALUE OF THE IsNullable PROPERTY.
getIsStatic()	RETURN THE VALUE OF THE isStatic PROPERTY.
setIsStatic(String)	SET THE VALUE OF THE isStatic PROPERTY.
getIsConstant()	RETURN THE VALUE OF THE isConstant PROPERTY.
setIsConstant(String)	SET THE VALUE OF THE isConstant PROPERTY.
getIsKey()	RETURN THE VALUE OF THE isKey PROPERTY.
setIsKey(String)	SET THE VALUE OF THE isKey PROPERTY.
getScope()	RETURN THE VALUE OF THE SCOPE PROPERTY.
setScope(String)	SET THE VALUE OF THE SCOPE PROPERTY.
getPersistence()	RETURN THE VALUE OF THE PERSISTENCE PROPERTY.
setPersistence(String)	SET THE VALUE OF THE PERSISTENCE PROPERTY.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getMetaClass()	RETURNS AN OBJECT OF TYPE MetaClass.

METHODS

NAME	DESCRIPTION
toString()	RETURNS A STRING REPRESENTATION OF THIS ATTRIBUTE.
copyAttributes()	COPIES THE ATTRIBUTES OF THE GIVEN ATTRIBUTE TO THIS ATTRIBUTE.

FIG.12C

Class AssociationRole

```
Object
  |
  +---MetaObject
      |
      +---AssociationRole
```

public class AssociationRole
extends MetaObject

DESCRIPTION

AN AssociationRole INSTANCE REPRESENTS AN ASSOCIATION END IN THE OBJECT MODEL OF A SOFTWARE SYSTEM.

PROPERTIES

NAME	TYPE	DESCRIPTION
constraints	STRING	THE CONSTRAINTS OF THE ASSOCIATION END IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS AssociationRole.
isAggregate	BOOLEAN	INDICATES THE ASSOCIATION END IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS AssociationRole IS AN AGGREGATE.
isNavigable	BOOLEAN	INDICATES THE ASSOCIATION END IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS AssociationRole IS NAVIGABLE.
foreignKeyName	STRING	THE NAME OF THE FOREIGN KEY USED BY OBJECTS OF THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THE MetaClass INSTANCE OF THIS AssociationRole TO ACCESS OBJECTS ON THE OTHER SIDE OF THE ASSOCIATION END.
multiplicity	INT – VALUES DEFINED IN CLASS CardinalityEnum	THE MULTIPLICITY OF THE ASSOCIATION END IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS AssociationRole.
scope	INT – VALUES DEFINED IN CLASS ScopeEnum	THE SCOPE OF THE ASSOCIATION END IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS AssociationRole.
containment	INT – VALUES DEFINED IN CLASS ContainmentEnum	THE CONTAINMENT OF THE ASSOCIATION END IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS AssociationRole.

CONSTRUCTORS

NAME	DESCRIPTION
AssociationRole()	CONSTRUCTS AN EMPTY AssociationRole OBJECT.

FIG.13A

ACCESSORS/MUTATORS

NAME	DESCRIPTION
getConstraints()	RETURN THE VALUE OF THE CONSTRAINTS PROPERTY.
setConstraints(String)	SET THE VALUE OF THE CONSTRAINTS PROPERTY.
getIsAggregate()	RETURN THE VALUE OF THE isAggregate PROPERTY.
setIsAggregate(String)	SET THE VALUE OF THE isAggregate PROPERTY.
getIsNavigable()	RETURN THE VALUE OF THE isNavigable PROPERTY.
setIsNavigable(String)	SET THE VALUE OF THE isNavigable PROPERTY.
getForeignKeyName()	RETURN THE VALUE OF THE foreignKeyName PROPERTY.
setForeignKeyName(String)	SET THE VALUE OF THE foreignKeyName PROPERTY.
getMultiplicity()	RETURN THE VALUE OF THE MULTIPLICITY PROPERTY.
setMultiplicity(String)	SET THE VALUE OF THE MULTIPLICITY PROPERTY.
getScope()	RETURN THE VALUE OF THE SCOPE PROPERTY.
getScope(String)	SET THE VALUE OF THE SCOPE PROPERTY.
getContainment()	RETURN THE VALUE OF THE CONTAINMENT PROPERTY.
setContainment(String)	SET THE VALUE OF THE CONTAINMENT PROPERTY.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getMetaClass()	RETURNS AN OBJECT OF TYPE MetaClass. THE MetaClass INSTANCE REPRESENTING THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT PARTICIPATES IN THE ASSOCIATION END IN THE MODEL REPRESENTED BY THIS AssociationRole.
getAssociation()	RETURNS AN OBJECT OF TYPE ASSOCIATION.

METHODS

NAME	DESCRIPTION
toString()	RETURNS A STRING REPRESENTATION OF THIS AssociationRole.
getRelatedRole()	RETURNS THE INSTANCE OF AssociationRole THAT REPRESENTS THE OTHER ASSOCIATION END IN THE SAME ASSOCIATION AS THE ASSOCIATION END IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS AssociationRole.
copyAttributes()	COPIES THE ATTRIBUTES VALUES OF THE GIVEN AssociationRole TO THIS AssociationRole.

FIG.13B

FIG.14A

Class Component

```
Object
  |
  +---MetaObject
        |
        +---Component
```

public class Component
extends MetaObject

DESCRIPTION

A COMPONENT INSTANCE REPRESENTS A COMPONENT IN THE OBJECT MODEL OF A SOFTWARE SYSTEM.

PROPERTIES

NAME	TYPE	DESCRIPTION
implementationTarget	STRING	THE IMPLEMENTATION TARGET OF THE COMPONENT IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS COMPONENT. THE USER-DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE ARE USED TO DEFINE THE IMPLEMENTATION TARGET. THE METAMACHINE BINDS THE COMPONENT TO THE METAPROJECT WHOSE NAME MATCHES THE COMPONENTS IMPLEMENTATION TARGET.

CONSTRUCTORS

NAME	DESCRIPTION
Component()	CONSTRUCTS AN EMPTY COMPONENT OBJECT.

ACCESSORS/MUTATORS

NAME	DESCRIPTION
getImplementationTarget()	RETURN THE VALUE OF THE implementationTarget PROPERTY.
setImplementationTarget(String)	SET THE VALUE OF THE implementationTarget PROPERTY.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getMetaClasses()	RETURNS AN OBJECT OF TYPE MetaClass. THE MetaClass INSTANCES THAT CORRESPOND TO THE CLASSES IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT BELONG TO THE COMPONENT IN THE MODEL THAT IS REPRESENTED BY THIS COMPONENT.
getSubsystem()	RETURNS AN OBJECT OF TYPE Subsystem.
getAssociations()	RETURNS AN OBJECT OF TYPE Association. THE ASSOCIATION INSTANCES THAT REPRESENT THE ASSOCIATIONS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT BELONG TO THE COMPONENT IN THE MODEL THAT IS REPRESENTED BY THIS COMPONENT.
getGeneralizations()	RETURNS AN OBJECT OF TYPE Generalization.

	THE GENERALIZATION INSTANCES THAT REPRESENT THE GENERALIZATIONS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT BELONG TO THE COMPONENT IN THE MODEL THAT IS REPRESENTED BY THIS COMPONENT.
getComponents()	RETURNS AN OBJECT OF TYPE <u>Component.</u>
getDependencies()	RETURNS AN OBJECT OF TYPE <u>Component.</u> THE COMPONENT INSTANCES THAT REPRESENT THE COMPONENTS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM ON WHICH THE COMPONENT IN THE MODEL THAT IS REPRESENTED BY THIS COMPONENT DEPENDS.

METHODS

NAME	DESCRIPTION
getVirtualPath()	RETURNS THE VIRTUAL PATH TO THE COMPONENT, WITH THE NODES IN THE PATH SEPARATED BY THE GIVEN SEPARATOR.
toString()	

FIG.14B

Class Generalization

```
Object
  |
  +---MetaObject
        |
        +---Generalization
```

FIG.15A

public class Generalization
extends MetaObject

DESCRIPTION
A GENERALIZATION INSTANCE REPRESENTS A GENERALIZATION IN THE OBJECT MODEL OF A SOFTWARE SYSTEM. A GENERALIZATION EXISTS WHENEVER ONE CLASS INHERITS FROM ANOTHER CLASS.

PROPERTIES

NAME	TYPE	DESCRIPTION
constraints	STRING	CONTAINS THE CONSTRAINTS OF THE GENERALIZATION IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS GENERALIZATION.
scope	INT – VALUES DEFINED IN CLASS ScopeEnum	INDICATES THE SCOPE OF THE GENERALIZATION IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS GENERALIZATION.

CONSTRUCTORS

NAME	DESCRIPTION
Generalization()	CONSTRUCTS AN EMPTY GENERALIZATION OBJECT.

ACCESSORS/MUTATORS

NAME	DESCRIPTION
getConstraints()	RETURN THE VALUE OF THE CONSTRAINTS PROPERTY.
setConstraints(String)	SET THE RETURN VALUE OF THE CONSTRAINTS PROPERTY.
getScope()	RETURN THE VALUE OF THE SCOPE PROPERTY.
setScope(String)	SET THE VALUE OF THE SCOPE PROPERTY.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getMetaClass()	RETURNS AN OBJECT OF TYPE MetaClass.
getSuperClass()	RETURNS AN OBJECT OF TYPE MetaClass. THE MetaClass INSTANCE CORRESPONDING TO THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT IS THE SUPER CLASS OF THE GENERALIZATION IN THE MODEL REPRESENTED BY THIS GENERALIZATION.
getSubClass()	RETURNS AN OBJECT OF TYPE MetaClass. THE MetaClass INSTANCE CORRESPONDING TO THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT IS THE SUBCLASS OF THE GENERALIZATION IN THE MODEL REPRESENTED BY THIS GENERALIZATION.

getModel()	RETURNS AN OBJECT OF TYPE Model. REPRESENTS THE OBJECT MODEL OF A SOFTWARE SYSTEM TO WHICH THE GENERALIZATION IN THE MODEL REPRESENTED BY THIS GENERALIZATION BELONGS.
getComponents()	RETURNS AN OBJECT OF TYPE Component.

METHODS

NAME	DESCRIPTION
toString()	RETURNS A STRING REPRESENTATION THIS GENERALIZATION.

FIG. 15B

Class MetaClass

```
Object
  |
  +---MetaObject
       |
       +---MetaClass
```

FIG. 16A

public class MetaObject
extends MetaObject

DESCRIPTION

A MetaClass INSTANCE REPRESENTS A CLASS IN AN OBJECT MODEL OF A SOFTWARE SYSTEM.

PROPERTIES

NAME	TYPE	DESCRIPTION
constraints	STRING	CONSTRAINTS STORE THE CONSTRAINTS OF THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM.
isLink	BOOLEAN	TRUE IF THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM IS AN ASSOCIATION CLASS.
isDerived	BOOLEAN	
isUtility	BOOLEAN	
isExternal	BOOLEAN	TRUE IF THE USER-DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE ARE USED TO INDICATE THAT THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM IS EXTERNAL. IN GENERAL, EXTERNAL CLASSES ARE USED BY THE MODELED SOFTWARE SYSTEM, BUT THEY ARE PROVIDED BY A DIFFERENT SOFTWARE SYSTEM.
isTemplate	BOOLEAN	TRUE IF THE USER-DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE ARE USED TO INDICATE THAT THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM IS A TEMPLATE.
isInterface	BOOLEAN	TRUE IF THE USER-DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE ARE USED TO INDICATE THAT THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM IS AN INTERFACE. INTERFACES DEFINE THE ATTRIBUTES AND OPERATIONS THAT MUST BE IMPLEMENTED BY A CLASS THAT REALIZES THE INTERFACE.
isEnum	BOOLEAN	TRUE IF THE USER-DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE ARE USED TO INDICATE THAT THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM IS AN ENUMERATION. ENUMERATIONS ARE CLASSES THAT HAVE ONLY INITIALIZED CLASS-SCOPE ATTRIBUTES WHOSE VALUES NEVER CHANGE (READONLY). GENERALLY, THEY ARE USED TO RESTRICT THE VALUE OF OTHER INSTANCE-SCOPE ATTRIBUTES IN THE SOFTWARE SYSTEM.
isComposite	BOOLEAN	

isDistributed	BOOLEAN	
overidability	INT - VALUES DEFINED IN CLASS OveridabilityEnum	INDICATES THE OVERRIDABILITY OF THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass.
persistence	INT - VALUES DEFINED IN CLASS PersistenceEnum	INDICATES THE PERSISTENCE OF THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass.
scope	INT - VALUES DEFINED IN CLASS ScopeEnum	INDICATES THE SCOPE OF THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass.
cardinality	INT - VALUES DEFINED CLASS CardinalityEnum	INDICATES THE TYPE OF THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass. A REGULAR CLASS ALLOWING MULTIPLE INSTANCES; A SINGLETON ALLOWING ONE INSTANCE; OR, A ONE WITH ALL CLASS-SCOPE ATTRIBUTES AND METHODS (E.G., STATIC).

CONSTRUCTORS

NAME	DESCRIPTION
MetaClass()	CONSTRUCTS AN EMPTY MetaClass OBJECT.

ACCESSORS / MUTATORS

NAME	DESCRIPTION
getConstraints()	RETURN THE VALUE OF THE CONSTRAINTS PROPERTY.
setConstraints(String)	SET THE VALUE OF THE CONSTRAINTS PROPERTY.
getIsLink()	RETURN THE VALUE OF THE isLink PROPERTY.
setIsLink(String)	SET THE VALUE OF THE isLink PROPERTY.
getIsDerived()	RETURN THE VALUE OF THE isDerived PROPERTY.
setIsDerived(String)	SET THE VALUE OF THE isDerived PROPERTY.
getIsUtility()	RETURN THE VALUE OF THE isUtility PROPERTY.
setIsUtility(Sring)	SET THE VALUE OF THE isUtility PROPERTY.
getIsExternal()	RETURN THE VALUE OF THE isExternal PROPERTY.
setIsExternal(String)	SET THE VALUE OF THE isExternal PROPERTY.
getIsTemplate()	RETURN THE VALUE OF THE isTemplate PROPERTY.
setIsTemplate(String)	SET THE VALUE OF THE isTemplate PROPERTY.
getIsInterface()	RETURN THE VALUE OF THE isInterface PROPERTY.
setIsInterface(String)	SET THE VALUE OF THE isInterface PROPERTY.
getIsEnum()	RETURN THE VALUE OF THE isEnum PROPERTY.
setIsEnum(String)	SET THE VALUE OF THE isEnum PROPERTY.
getIsComposite()	RETURN THE VALUE OF THE isComposite PROPERTY.
setIsComposite(String)	SET THE VALUE OF THE isComposite PROPERTY.
getIsDistributed()	RETURN THE VALUE OF THE isDistributed PROPERTY.
setIsDistributed(String)	SET THE VALUE OF THE isDistributed PROPERTY.
getOveridability()	RETURN THE VALUE OF THE OVERIDABILITY PROPERTY.
setOveridability(String)	SET THE VALUE OF THE OVERIDABILITY PROPERTY.

FIG. 16B

getPersistence()	RETURN THE VALUE OF THE PERSISTENCE PROPERTY.
setPersistence(String)	SET THE VALUE OF THE PERSISTENCE PROPERTY.
getScope()	RETURN THE VALUE OF THE SCOPE PROPERTY.
setScope(String)	SET THE VALUE OF THE SCOPE PROPERTY.
getCardinality()	RETURN THE VALUE OF THE CARDINALITY PROPERTY.
setCardinality(String)	SET THE VALUE OF THE CARDINALITY PROPERTY.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getHoldingPackage()	RETURNS AN OBJECT OF TYPE Package. THE holdingPackage REPRESENTS THE PACKAGE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM TO WHICH THE CLASS REPRESENTED BY THIS MetaClass BELONGS.
getAttributes()	RETURNS AN OBJECT OF TYPE Attribute. THE ATTRIBUTES OF THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass.
getOperations()	RETURNS AN OBJECT OF TYPE Operation. THE OPERATIONS OF THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass.
getGeneralizations()	RETURNS AN OBJECT OF TYPE Generalization. THE GENERALIZATIONS THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass PARTICIPATES IN AS A SUBCLASS.
getGeneralizations()	RETURNS AN OBJECT OF TYPE Generalization.
getRoles()	RETURNS AN OBJECT OF TYPE AssociationRole. THE ASSOCIATION ENDS OF THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass PARTICIPATES.
getComponents()	RETURNS AN OBJECT OF TYPE Component. THE COMPONENTS IN WHICH THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass IS REALIZED.
getLinkAssociation()	RETURNS AN OBJECT OF TYPE Association. THE ASSOCIATION OF WHICH THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass IS AN ASSOCIATION CLASS.
getRealizations()	RETURNS A COLLECTION OF Realization OBJECTS. THE REALIZATIONS IN WHICH THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass PARTICIPATES AS IMPLEMENTING THE CORRESPONDING INTERFACE.
getRealizations()	RETURNS A COLLECTION OF Realization OBJECTS.
getModel()	RETURNS AN OBJECT OF TYPE Model. REPRESENTS THE OBJECT MODEL OF A SOFTWARE SYSTEM TO WHICH THE CLASS IN THE MODEL REPRESENTED BY THIS MetaClass BELONGS.

FIG. 16C

METHODS

NAME	DESCRIPTION
copyAttributes()	COPIES THE ATTRIBUTES FROM THE GIVEN CLASS TO THIS CLASS.
getSuperClass()	IF THE CLASS IN THE MODEL OF THE SOFTWARE SYSTEM INHERITS FROM ANOTHER CLASS IN THE MODEL, RETURN THE METACLASS INSTANCE THAT REPRESENTS THE SUPERCLASS. OTHERWISE, RETURN NULL.
getAllSubClasses()	RETURNS ALL THE METACLASS INSTANCES THAT REPRESENT CLASSES IN THE MODEL OF THE SOFTWARE SYSTEM THAT INHERIT FROM THE CLASS IN THE MODEL REPRESENTED BY THIS MetaClass.
getAllSuperClasses()	RETURNS ALL THE METACLASS INSTANCES THAT REPRESENT CLASSES IN THE MODEL OF THE SOFTWARE SYSTEM FROM WHICH THE CLASS IN THE MODEL REPRESENTED BY THIS MetaClass INHERITS.
isSuperClassOf()	RETURN TRUE IF THE CLASS IN THE SOFTWARE SYSTEM'S MODEL REPRESENTED BY THIS MetaClass INSTANCE INHERITS FROM THE CLASS IN THE MODEL REPRESENTED BY THE GIVEN MetaClass INSTANCE. OTHERWISE, RETURN FALSE.
getOneToManyAssociationRoles()	RETURNS THE META ROLES REPRESENTING THE ONE-TO-ONE AND ONE-TO-MANY ROLES IN THE MODEL OF THE SOFTWARE SYSTEM IN WHICH THE CLASS IN THE MODEL REPRESENTED BY THIS INSTANCE OF MetaClass PARTICIPATES.
getToOneAssociationRoles()	RETURNS THE META ROLES REPRESENTING THE ONE-TO-ONE AND MANY-TO-ONE ROLES IN THE MODEL OF THE SOFTWARE SYSTEM IN WHICH THE CLASS IN THE MODEL REPRESENTED BY THIS INSTANCE OF THE MetaClass PARTICIPATES.
getOneToManyOrManyToManyAssociationRoles()	RETURNS THE META ROLES REPRESENTING THE ONE-TO-MANY AND MANY-TO-MANY ROLES IN THE MODEL OF THE SOFTWARE SYSTEM IN WHICH THE CLASS IN THE MODEL REPRESENTED BY THIS INSTANCE OF THE MetaClass PARTICIPATES.
getManyToManyAssociationRoles()	RETURNS THE META ROLES REPRESENTING THE MANY-TO-MANY ROLES IN THE MODEL OF THE SOFTWARE SYSTEM IN WHICH THE CLASS IN THE

FIG. 16D

	MODEL REPRESENTED BY THIS INSTANCE OF THE MetaClass PARTICIPATES.
hasPersistentReference()	RETURNS TRUE IF THE CLASS IN THE MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS MetaClass CONTAINS A PERSISTENT REFERENCE TO THE CLASS IN THE MODEL REPRESENTED BY THE MetaClass CONTAINED IN THE GIVEN ROLER. OTHERWISE, RETURN FALSE.
toString()	RETURNS A STRING REPRESENTATION OF THE MetaClass.

FIG. 16E

Class MetaObject

Object
 |
 +---MetaObject

public class MetaObject

DESCRIPTION

THE BASE CLASS OF MOST OBJECTS IN THE META MODEL.

PROPERTIES

NAME	TYPE	DESCRIPTION
objId	STRING	THE OBJECT ID OF THE MODEL ELEMENT. THE OBJECT ID UNIQUELY IDENTIFIES A MODEL ELEMENT IN AN OBJECT MODEL OF A SOFTWARE SYSTEM.
name	STRING	THE NAME OF THE MODEL ELEMENT.
description	STRING	A DESCRIPTION OF THE MODEL ELEMENT. THE USER-DEFINED EXTENSIONS OF AN OBJECT MODELING LANGUAGE ARE OFTEN USED TO SET DESCRIPTION'S VALUE.
stereotype	STRING	THE STEREOTYPE OF THE MODEL ELEMENT. STEREOTYPES ARE USER-DEFINED EXTENSIONS OF UML.

CONSTRUCTORS

NAME	DESCRIPTION
MetaObject()	CONSTRUCTS AN EMPTY MetaObject OBJECT.

ACCESSORS/MUTATORS

NAME	DESCRIPTION
getObjId()	RETURN THE VALUE OF THE objId PROPERTY.
setObjId(String)	SET THE VALUE OF THE objId PROPERTY.
getName()	RETURN THE VALUE OF THE NAME PROPERTY.
setName(String)	SET THE VALUE OF THE NAME PROPERTY.
getDescription()	RETURN THE VALUE OF THE DESCRIPTION PROPERTY.
setDescription(String)	SET THE VALUE OF THE DESCRIPTION PROPERTY.
getStereotype()	RETURN THE VALUE OF THE STEREOTYPE PROPERTY.
setStereotype(String)	SET THE VALUE OF THE STEREOTYPE PROPERTY.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getTags()	RETURNS A COLLECTION OF <u>Tag</u> OBJECTS. THE TAGS OF THE MODEL ELEMENT IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MetaObject.

FIG.17A

METHODS

NAME	DESCRIPTION
getTaggedValue()	RETURNS THE VALUE OF THE GIVEN TAG.
setTaggedValue()	SETS THE GIVEN TAG TO THE GIVEN VALUE.
getTags()	RETURN THE TAGGED VALUES OF THIS MetaObject.
copyAttributes()	COPIES THE ATTRIBUTES VALUES OF THE GIVEN MetaObject TO THIS MetaObject.
hasStereotype()	RETURNS TRUE IF THE MetaObject HAS THE GIVEN STEREOTYPE.
toString()	RETURNS A STRING REPRESENTATION OF THIS MetaObject.

FIG. 17B

Class Model

```
Object
  |
  +---MetaObject
       |
       +---Model
```

FIG.18A

public class Model
extends MetaObject

DESCRIPTION

THE ROOT ELEMENT OF AN OBJECT MODEL OF A SOFTWARE SYSTEM.

PROPERTIES

NAME	TYPE	DESCRIPTION
version	STRING	THE VERSION OF THE MODEL.
outputPath	STRING	THE PATHNAME OF WHERE METAPROGRAMS GENERATE OUTPUT.

CONSTRUCTORS

NAME	DESCRIPTION
Model()	CONSTRUCTS AN EMPTY MODEL OBJECT.

ACCESSORS/MUTATORS

NAME	DESCRIPTION
getVersion()	RETURN THE VALUE OF THE VERSION PROPERTY.
setVersion(String)	SET THE VALUE OF THE VERSION PROPERTY.
getOutputPath()	RETURN THE VALUE OF THE outputPath PROPERTY.
setOutputPath(String)	SET THE VALUE OF THE outputPath PROPERTY.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getMetaClasses()	RETURNS AN OBJECT OF TYPE MetaClass. THE MetaClass INSTANCES REPRESENTING THE CLASSES IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MODEL.
getSubsystems()	RETURNS AN OBJECT OF TYPE Subsystem. THE SUBSYSTEM INSTANCES REPRESENTING THE SUBSYSTEMS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MODEL.
getPackages()	RETURNS AN OBJECT OF TYPE Package. THE PACKAGE INSTANCES REPRESENTING THE PACKAGES IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MODEL.
getAssociations()	RETURNS AN OBJECT OF TYPE Association. THE ASSOCIATION INSTANCES REPRESENTING THE ASSOCIATIONS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MODEL.
getGeneralizations()	RETURNS AN OBJECT OF TYPE Generalization. THE GENERALIZATION INSTANCES REPRESENTING THE GENERALIZATIONS IN

	THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MODEL.
getRealizations()	RETURNS A COLLECTION OF Realization OBJECTS. THE REALIZATION INSTANCES REPRESENTING THE REALIZATIONS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS MODEL.
getMetaCoders()	RETURNS AN OBJECT OF TYPE MetaCoder.

METHODS

NAME	DESCRIPTION
toString()	RETURNS A STRING REPRESENTATION OF THIS MODEL.
findMetaClass()	RETURNS THE INSTANCE OF MetaClass WHOSE OBJECT ID MATCHES THE GIVEN OBJECT ID. RETURNS NULL IF NO SUCH MetaClass EXISTS.
findComponent()	RETURNS THE COMPONENT INSTANCE WHOSE OBJECT ID MATCHES THE GIVEN OBJECT ID. RETURNS NULL IF NO SUCH COMPONENT INSTANCE EXISTS.
findMetaClassesByName()	RETURNS A COLLECTION OF MetaClass INSTANCES WHOSE NAMES MATCH THE GIVEN NAME. RETURNS NULL IF NO SUCH MetaClass INSTANCES EXIST.
findAssociation()	RETURNS THE INSTANCE OF ASSOCIATION WHOSE OBJECT ID MATCHES THE GIVEN OBJECT ID. RETURNS NULL IF NO SUCH INSTANCE EXISTS.
findGeneralization()	RETURNS THE INSTANCE OF GENERALIZATION WHOSE OBJECT ID MATCHES THE GIVEN OBJECT ID. RETURNS NULL IF NO SUCH INSTANCE EXISTS.

FIG. 18B

Class Operation

```
Object
  |
  +---MetaObject
      |
      +---Operation
```

FIG.19A

public class Operation
extends MetaObject

DESCRIPTION

AN OPERATION INSTANCE REPRESENTS A METHOD OF A CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM.

PROPERTIES

NAME	TYPE	DESCRIPTION
returnType	STRING	THE RETURN TYPE OF THE METHOD IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS OPERATION.
preconditions	STRING	THE PRECONDITIONS OF THE METHOD OF THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS OPERATION.
postconditions	STRING	THE POSTCONDITIONS OF THE METHOD OF THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS OPERATION.
semantics	STRING	THE SEMANTICS OF THE METHOD OF THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS OPERATION.
isStatic	BOOLEAN	TRUE IF THE METHOD OF THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS OPERATOR IS STATIC. STATIC METHODS HAVE CLASS SCOPE. THE USER DEFINED EXTENSION OF THE OBJECT MODELING LANGUAGE ARE SOMETIMES USED TO GIVE THIS INDICATION.
isConstant	BOOLEAN	DEPRICATED.
isFriend	BOOLEAN	DEPRICATED. INDICATES THE METHOD OF THE CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS OPERATOR IS A FRIEND. THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE ARE USED TO GIVE THIS INDICATION.
isInline	BOOLEAN	DEPRICATED. INDICATES THAT THE METHOD OF THE CLASS IN THE MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS OPERATOR IS INLINE. THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE ARE USED TO PROVIDE THIS INDICATION.
IsTemplate	BOOLEAN	DEPRICATED.

isDistributed	BOOLEAN	DEPRICATED. TRUE IF THE METHOD OF THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS OPERATOR IS DISTRIBUTED. THE USER DEFINED EXTENSIONS OF THE OBJECT MODELING LANGUAGE ARE USED TO PROVIDE THE INDICATION.
overidability	INT – VALUES DEFINED IN CLASS <u>OveridabilityEnum</u>	INDICATES THE OVERIDABILITY OF THE METHOD IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS OPERATION.
scope	INT – VALUES DEFINED IN CLASS <u>ScopeEnum</u>	

CONSTRUCTORS

NAME	DESCRIPTION
Operation()	CONSTRUCTS AN EMPTY OPERATION OBJECT.

ACCESSORS / MUTATORS

NAME	DESCRIPTION
getReturnType()	RETURN THE VALUE OF THE *returnType* PROPERTY.
setReturnType(String)	SET THE VALUE OF THE returnType PROPERTY.
getPreconditions()	RETURN THE VALUE OF THE PRECONDITIONS PROPERTY.
setPreconditions(String)	SET THE VALUE OF THE PRECONDITIONS PROPERTY.
getPostconditions()	RETURN THE VALUE OF THE POSTCONDITIONS PROPERTY.
setPostconditions(String)	SET THE VALUE OF THE POSTCONDITIONS PROPERTY.
getSemantics()	RETURN THE VALUE OF THE SEMANTICS PROPERTY.
setSemantics(String)	SET THE VALUE OF THE SEMANTICS PROPERTY.
getIsStatic()	RETURN THE VALUE OF THE isStatic PROPERTY.
setIsStatic(String)	SET THE VALUE OF THE isStatic PROPERTY.
getIsConstant()	RETURN THE VALUE OF THE isConstant PROPERTY.
setIsConstant(String)	SET THE VALUE OF THE isConstant PROPERTY.
getIsFriend()	RETURN THE VALUE OF THE isFriend PROPERTY.
setIsFriend(String)	SET THE VALUE OF THE isFriend PROPERTY.
getIsInline()	RETURN THE VALUE OF THE isInline PROPERTY.
setIsInline(String)	SET THE VALUE OF THE isInline PROPERTY.
getIsTemplate()	RETURN THE VALUE OF THE isTemplate PROPERTY.
setIsTemplate(String)	SET THE VALUE OF THE isTemplate PROPERTY.
getIsDistributed()	RETURN THE VALUE OF THE isDistributed PROPERTY.
setIsDistributed(String)	SET THE VALUE OF THE isDistributed PROPERTY.
getOveridability()	RETURN THE VALUE OF THE OVERIDABILITY PROPERTY.
setOveridability(String)	SET THE VALUE OF THE OVERIDABILITY PROPERTY.
getScope()	RETURN THE VALUE OF THE SCOPE PROPERTY.
setScope(String)	SET THE VALUE OF THE SCOPE PROPERTY.

FIG. 19B

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getMetaClass()	RETURNS AN OBJECT OF TYPE MetaClass.
getParameters()	RETURNS AN OBJECT OF TYPE Parameter. THE PARAMETER INSTANCES REPRESENTING PARAMETERS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT ARE PARAMETERS TO THE METHOD IN THE MODEL REPRESENTED BY THIS OPERATION.

METHODS

NAME	DESCRIPTION
toString()	RETURNS A STRING REPRESENTATION OF THIS OPERATOR.
copyAttributes()	COPIES THE ATTRIBUTES VALUES OF THE GIVEN OPERATOR TO THIS OPERATOR.

FIG. 19C

Class Package

```
Object
  |
  +---MetaObject
        |
        +---Package
```

public class Package
extends MetaObject

DESCRIPTION
A PACKAGE INSTANCE REPRESENTS A PACKAGE IN AN OBJECT MODEL OF A SOFTWARE SYSTEM.

CONSTRUCTORS

NAME	DESCRIPTION
Package()	CONSTRUCTS AN EMPTY PACKAGE OBJECT.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getMetaClasses()	RETURNS AN OBJECT OF TYPE MetaClass. THE MetaClass INSTANCES THAT CORRESPOND TO THE CLASSES IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT BELONG TO THE PACKAGE IN THE MODEL THAT IS REPRESENTED BY THIS PACKAGE.
getChildren()	RETURNS AN OBJECT OF TYPE Package. THE PACKAGE INSTANCES OF THE PACKAGES IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT REPRESENT THE CHILDREN PACKAGES IN THE MODEL REPRESENTED BY THIS PACKAGE.
getParent()	RETURNS AN OBJECT OF TYPE Package. THE PACKAGE INSTANCE OF THE PACKAGE IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT REPRESENTS THE PARENT PACKAGE IN THE MODEL REPRESENTED BY THIS PACKAGE.
getModel()	RETURNS AN OBJECT OF TYPE Model. REPRESENTS THE OBJECT MODEL OF A SOFTWARE SYSTEM TO WHICH THE PACKAGE IN THE MODEL REPRESENTED BY THIS PACKAGE BELONGS.

METHODS

NAME	DESCRIPTION
toString()	RETURNS A STRING REPRESENTATION OF THE PACKAGE.

FIG.20

Class Parameter

```
Object
  |
  +---MetaObject
        |
        +---Parameter
```

public class Parameter
extends MetaObject

DESCRIPTION

A META PARAMETER REPRESENTS A PARAMETER TO A METHOD IN THE MODEL OF A SOFTWARE SYSTEM.

PROPERTIES

NAME	TYPE	DESCRIPTION
dataType	STRING	THE DATA TYPE OF THE PARAMETER IN THE MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS "META" PARAMETER.
modifier	STRING	THE MODIFIER OF THE PARAMETER IN THE MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS "META" PARAMETER.
defaultValue	STRING	THE DEFAULT VALUE OF THE PARAMETER IN THE MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS "META" PARAMETER.
isConstant	BOOLEAN	TRUE IF THE PARAMETER IN THE MODEL OF THE SOFTWARE SYSTEM REPRESENTED BY THIS "META" PARAMETER IS A CONSTANT.

CONSTRUCTORS

NAME	DESCRIPTION
Parameter()	CONSTRUCTS AN EMPTY PARAMETER OBJECT.

ACCESSORS/MUTATORS

NAME	DESCRIPTION
getDataType()	RETURN THE VALUE OF THE dataType PROPERTY.
setDataType(String)	SET THE VALUE OF THE dataType PROPERTY.
getModifier()	RETURN THE VALUE OF THE MODIFIER PROPERTY.
setModifier(String)	SET THE VALUE OF THE MODIFIER PROPERTY.
getDefaultValue()	RETURN THE VALUE OF THE DefaultValue PROPERTY.
setDefaultValue(String)	SET THE VALUE OF THE DefaultValue PROPERTY.
getIsConstant()	RETURN THE VALUE OF THE isConstant PROPERTY.
setIsConstant(String)	SET THE VALUE OF THE isConstant PROPERTY.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getOperation()	RETURNS AN OBJECT OF TYPE OPERATION.

FIG.21A

METHODS

NAME	DESCRIPTION
toString()	RETURNS A STRING REPRESENTATION OF THIS "META" PARAMETER.

FIG. 21B

Class Realization

```
Object
  |
  +---MetaObject
        |
        +---Realization
```

public class Realization
extends MetaObject

DESCRIPTION

A REALIZATION INSTANCE REPRESENTS A REALIZATION OF AN INTERFACE BY A CLASS IN THE OBJECT MODEL OF THE SOFTWARE SYSTEM.

PROPERTIES

NAME	TYPE	DESCRIPTION
constraints	STRING	THE CONSTRAINTS OF THIS REALIZATION.

CONSTRUCTORS

NAME	DESCRIPTION
Realization()	CONSTRUCTS AN EMPTY REALIZATION OBJECT.

ACCESSORS/MUTATORS

NAME	DESCRIPTION
getConstraints()	RETURN THE VALUE OF THE CONSTRAINTS PROPERTY.
setConstraints(String)	SET THE VALUE OF THE CONSTRAINTS PROPERTY.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getMetaClass()	RETURNS AN OBJECT OF TYPE MetaClass.
getInterfaceClass()	RETURNS AN OBJECT OF TYPE MetaClass. THE MetaClass INSTANCE REPRESENTING THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT DEFINES THE INTERFACE BEING REALIZED.
getImplClass()	RETURNS AN OBJECT OF TYPE MetaClass. THE MetaClass INSTANCE REPRESENTING THE CLASS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT IMPLEMENTS THE INTERFACE BEING REALIZED.
getModel()	RETURNS AN OBJECT OF TYPE Model.

FIG.22

Class Subsystem

```
Object
  |
  +---MetaObject
      |
      +---Subsystem
```

public class Subsystem
extends MetaObject

DESCRIPTION

AN INSTANCE OF SUBSYSTEM REPRESENTS A SUBSYSTEM IN THE MODEL OF THE SOFTWARE SYSTEM. A SUBSYSTEM IS USED TO GROUP COMPONENTS AND TYPICALLY AFFECTS THE PHYSICAL LAYOUT OF IMPLEMENTATION OF THE SOFTWARE SYSTEM.

CONSTRUCTORS

NAME	DESCRIPTION
Subsystem()	CONSTRUCTS AN EMPTY SUBSYSTEM OBJECT.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getChildren()	RETURNS AN OBJECT OF TYPE Subsystem. THE SUBSYSTEM INSTANCES OF THE SUBSYSTEMS IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT REPRESENT THE CHILDREN SUBSYSTEMS IN THE MODEL REPRESENTED BY THIS SUBSYSTEM.
getParent()	RETURNS AN OBJECT OF TYPE Subsystem. THE SUBSYSTEM INSTANCE OF THE SUBSYSTEM IN THE OBJECT MODEL OF A SOFTWARE SYSTEM THAT REPRESENTS THE PARENT SUBSYSTEM IN THE MODEL REPRESENTED BY THIS SUBSYSTEM.
getModel()	RETURNS AN OBJECT OF TYPE Model. REPRESENTS THE OBJECT MODEL OF A SOFTWARE SYSTEM TO WHICH THE CLASS IN THE MODEL REPRESENTED BY THIS MetaClass BELONGS.
getComponents()	RETURNS AN OBJECT OF TYPE Component. THE COMPONENTS BELONGING TO THE SUBSYSTEM IN THE OBJECT MODEL OF A SOFTWARE SYSTEM REPRESENTED BY THIS SUBSYSTEM.

METHODS

NAME	DESCRIPTION
toString()	RETURNS A STRING REPRESENTATION OF THE SUBSYSTEM.
getVirtualPath()	RETURNS THE VIRTUAL PATH OF THE SUBSYSTEM WITH EACH NODE SEPARATED BY THE GIVEN SEPARATOR. IN GENERAL, THE VIRTUAL PATH OF A SUBSYSTEM IS USED TO DETERMINE THE PATHNAME TO THE GENERATED COMPONENTS THAT COMPRISE THE SUBSYSTEM.

FIG.23

Class Tag

```
Object
  |
  +---Tag
```

public class Tag

DESCRIPTION

A TAG INSTANCE REPRESENTS A TAGGED VALUE BOUND TO A MODEL ELEMENT IN AN OBJECT MODEL OF A SOFTWARE SYSTEM.

PROPERTIES

NAME	TYPE	DESCRIPTION
name	STRING	THE NAME OF THE TAG.
value	STRING	THE TAG'S VALUE.

CONSTRUCTORS

NAME	DESCRIPTION
Tag()	CONSTRUCTS AN EMPTY TAG OBJECT.

ACCESSORS/MUTATORS

NAME	DESCRIPTION
getName()	RETURN THE VALUE OF THE NAME PROPERTY.
setName(String)	SET THE VALUE OF THE NAME PROPERTY.
getValue()	RETURN THE VALUE OF THE VALUE PROPERTY.
setValue(String)	SET THE VALUE OF THE VALUE PROPERTY.

ASSOCIATED OBJECTS

NAME	DESCRIPTION
getMetaObject()	RETURNS AN OBJECT OF TYPE MetaObject.

FIG.24

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/09930

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : G06F 9/44
US CL :717/1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 717/1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPTO EIC Collection on Object-Oriented Software Development tools

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WEST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Rational Software Corporation, Rational Rose version 4.0, Using Rational Rose 4.0, Chapters 3 - 7, November 1996	1-40
Y	Rational Software Corporation, Rational Rose, Round-Trip Engineering with Rational Rose/C++ version 4.0 , Chapter 6 pages 228, November 1996	1-40
Y	Rational Software Corporation, Rational Rose version 4.0, Unifi ed Modeling Language, Booch & OMT Quick Reference , November 1996	1-40

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document published on or after the international filing date
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Date of the actual completion of the international search	Date of mailing of the international search report
20 MAY 2001	06 JUN 2001

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	TODD INGBERG James R. Matthews
Facsimile No. (703) 305-3230	Telephone No. (703) 305-3800